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Pioneering in 1933

WHEN Yadkin Valley ceased to be a frontier, Daniel Boone moved on to the Carolinas. When Kentucky became "too crowded," he marched on to the Kanawha, and finally into what is now Missouri—finding out what was there, battling with wilderness and Indian, conquering new conditions.

Following hard upon the heels of Boone came the "empire builders" with their railroads. These poineers smoothed the way for those who established farms and factories and cities—all the institutions of a civilization that must always be in process of development and refinement.

Supporting and many times leading all this pioneering progress, were the successive technical assaults on the frontiers of discovery and invention. Steamboat, locomotive, traction car, automobile, airplane came in quick succession—telegraph, telephone, radio, television. Each presented new conditions to be conquered, and vistas limited only by the bounds of imagination.

In the wake of all these, but often in the van, came the development of alloy steels, non-ferrous metals and alloys, non-metallic materials, antifriction bearings, electric motors and controls, diecastings, molded plastics, units for hydraulic operation, and finally the photo-electric cell—each the result of supreme pioneering effort.

It is unlikely that something to create a new industry will suddenly appear to lead the world to renewed prosperity, although things undreamed of are bound to come. At least the basic products for the conquest of sea, land and air, for the annihilation of time and space, are at hand.

Whether geographic or technical, pioneering is no longer a mere search for new frontiers to conquer. Pioneering in 1933 consists in a huge variety of vital jobs to apply the discoveries of research, to adopt the new materials, parts and manufacturing processes, to develop refined designs and to create newness through better performance and appearance. Greater salability will follow almost as a matter of course.

After all, every engineering job is a pioneering job. Like the early pioneer, the product engineer must have courage—courage to challenge the public, and sometimes his own company, with radically new designs. Above all, he must have—in addition to exact knowledge of technology and the skill of experience—the imagination to envision a criterion of perfection.

* * * *

Some time ago the editors of *Product Engineering* decided to gather together examples of engineering pioneering and to publish them, not as "success stories," but rather as technical articles showing how the designers met and conquered particular problems.

In this number you will find how the problem of adequate bearings for one-hundred-ton gyroscopes was solved. You will find how the Jacquard principle was adapted from the loom to the circular knitting machine. You will see some of the solutions of the problems met and conquered in the designing of the Castype—a new machine that is destined to bring certain jobs of mechanical typesetting from the printshop to the office.

Volume 4

With this number *Product Engineering* begins its fourth volume. Founded three years ago by the McGraw-Hill Publishing Company to serve the product development engineer it goes forward under the same name and with the following editorial staff: Kenneth H. Condit, editor; William W. Dodge, managing editor; George F. Nordenholt, associate editor; Fred H. Colvin, consulting editor; John W. Shaver (Cleveland); Paul Wooton (Washington); Norma J. Van Ness.

Overcoming Bearing Deficiencies

A detailed account of the steps in the development of a highly refined design of cylindrical type bearing

ALEXANDER E. SCHEIN

Chief Engineer, Stabilizer Department
Sperry Gyroscope Company

In the design of bearings for the rotors of gyroscopes, ordinary commercial practice is not good enough. Bearing surface speeds are high, up to 4300 ft. per min., and heavy loads must be carried. The rotors of the stabilizers on the new ship *Conte di Savoia,* the first passenger ship to be equipped with gyroscopic stabilizers, weigh 100 tons. The maximum bearing load exerted by such rotors when in action may be as high as 200 tons. Other factors to consider are: The rotors are kept turning continuously; the bearing friction losses must be low in order to minimize the power required to drive the rotor; and the design of the bearings must be such that practically no service attention will be required. From this it follows that wear must be insignificant.

In order that the bearings be capable of carrying such high loads and yet be of reasonable size—those on the *Conte di Savoia* are 18 in. in diameter—the design must be refined so as to permit high unit bearing pressures. There are probably no bearings, operating under conditions such as imposed upon the bearings of gyroscope rotors, carrying equally high pressures per unit of projected area. It was only by eliminating the factors that contribute to limiting the load-bearing capacity, that there was finally developed a design that satisfactorily meets the requirements. Probably no other commercial bearings have been refined to an equal degree.

In the ordinary commercial bearing of a diameter of 8 in. or more, tolerances are in the order of 0.002 in. But the thickness of the load-carrying oil film is only 0.0005 in. on the "off" side of the bearing, increasing up to 0.0008 in. at the "on" side. It is apparent that when dealing with such thin films, a tolerance of 0.002 in. is entirely too great if unbroken film lubrication is to be maintained. Also, when the surface of such a machined bearing is viewed under the microscope, it is shown to have saw-toothed ridges, as indicated in Fig. 1. Ridges break up the continuity of the oil film, diminish the area of load-bearing film surface, and thereby increase the maximum oil film pressure required for sustaining a given bearing load. The first step then is to obtain a journal surface of greater accuracy and smoothness.

Lapped Journals

Grinding is naturally the method resorted to for procuring greater accuracy and a smoother surface. Accuracies of the order of 0.0005 in. can thus be obtained. But even such a refinement is insufficient. The next and final step is to lap the journal, thereby procuring an accuracy of the order of 0.0001 in., this tolerance being well within the minimum thickness of the oil film. Such a surface will permit not only maximum unit pressures but also will result in a maximum effective area of load-bearing film surface.

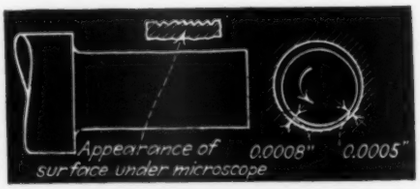


Fig. 1—If the journal is only machined, the surface will have microscopic ridges

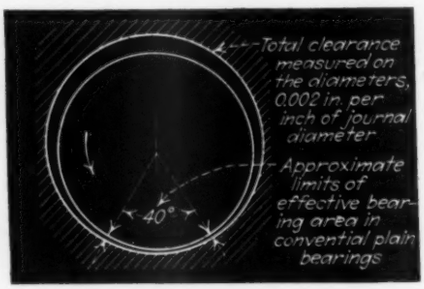

Total clearance measured on the diameters, 0.002 in. per inch of journal diameter
Approximate limits of effective bearing area in convential plain bearings
40°

Fig. 2—In the conventional design, effective bearing area is limited to a 40 to 50 deg. sector

It is interesting to note that some engineers claimed that the lapped surface would be too smooth. It was though that there would be insufficient adhesion between the oil film and the journal surface to draw the oil film through the bearing. Our experience over the past 14 years has shown that this is not so.

Having established what might be considered a perfect journal, the next element to refine is the design of the bearing. In Fig. 2 is shown in exaggerated form the clearance between the journal and its bearing while in operation. In ordinary practice, this clearance is approximately 0.002 in. per in. of diameter and is usually obtained by simply making the bore of the bearing that much greater than the diameter of the journal. Thus, for an 18 in. diameter journal, the bore would be 18.036 in.

With the journal resting at the bottom of the bearing as shown in Fig. 2, the oil film thickness at the "on" side will be about 0.0008 in., and on the "off" side, about 0.0005 in. On account of the difference between the radii of curvature of the journal surface and the bore of the bearing, it

follows that the angle subtended by the oil film cannot possibly be 180 deg. In the figure this angle is indicated as 40 deg., although it will vary with the diameter of the journal and the amount of clearance between the journal and bearing, and may perhaps be as high as 50 deg. This immediately suggests another possible method of increasing bearing capacity, namely by increasing the angle subtended by the oil film. Of course, it never could be 180 deg., as that would not permit the journal to shift in the bearing in order to establish the clearance for the oil film. However, by approaching the value of 120 deg., considerable increase in load carrying capacity is to be expected.

Increased Effective Area

When the conditions are such that the bearing load is at all times vertically downward, some designers make the diameter of the lower half of the bearing practically the same as the diameter of the journal, permitting merely sufficient clearance to establish the necessary oil film. In such a design, the effective bearing area is increased considerably. But in gyroscopes, the direction of the bearing load will vary. There are two distinct loads—one the main load and the other a secondary load whose direction is at right angles to that of the main load—and the bearing load will be exerted in any one of four directions.

The construction shown in Fig. 3 is practically self-explanatory. The nominal clearance used in the design of this bearing is 0.002 in. per in. of diameter, which conforms to the generally accepted practice. But in this special design, the bore of the bearing is comprised of four distinct sections, the radius of curvature of each section being equal to the radius of the journal plus a clearance equal to the thickness of the oil film. In manufacture, each section is first machined to a radius somewhat larger than that of the journal, the centers of curvature being as shown in the figure. The surfaces are then scraped to obtain an additional clearance equal to the thickness of the oil film. Exactness is obtained by scraping the bearing to fit a mandrel. The importance that is attached to this hand-scraping operation can be gaged from the fact that about 10 hours of hand scraping are required in finishing an 18-in. diameter bearing.

The longitudinal grooves between the sections of the babbitt bearing extend approximately 80 per cent of the bearing length, these grooves being closed off at each end in order to prevent the escape of lubricating oil. Using forced flood lubrication, the oil flows through the longitudinal grooves and furnishes a continuous supply of lubricant to the active quadrant of the bearing, thereby maintaining the oil film. The excess oil serves to keep the bearing cool.

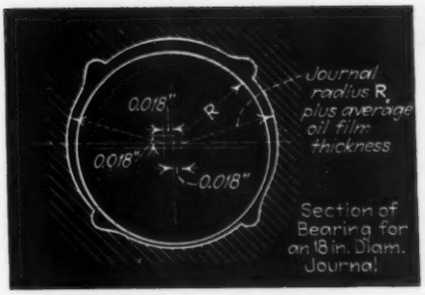


Fig. 3—In this design the bearing surface is in four sections separated by longitudinal oil grooves

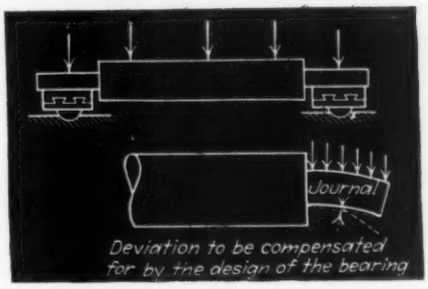


Fig. 4—Design of the bearing can be made to compensate for the deflection of the journal

A study of the design shown in Fig. 3 shows that the effective bearing area has been increased from a maximum of about 50 deg. of subtended arc, as found in the ordinary bearing, to about 110 deg. for the two main sections of the bearing surfaces that are contributing to the support of the load on the journal. It should also be noted that the nominal clearance—in this case, 0.002 in. per in. of diameter—plays no part in the operation of the bearing. This clearance could be increased to accommodate a greater volume of flood lubrication, or could be even somewhat decreased without in any way affecting the bearing performance or capacity.

Thus far we have considered only the diameters of the journal and bearings and the condition of the cylindrical bearing surface. What is perhaps of even greater importance is the part played by the deflection of the rotor shaft at the journal. Although the bearings are made self-aligning, as indicated in Fig. 4, the reaction at the bearings will be such as to cause an appreciable deflection of the shaft. This deflection will completely upset the otherwise uniform longitudinal load distribution, creating extremely high unit pressures at the center and near the ends of the journal. This, of course, will considerably decrease the load-carrying capacity of the bearing, or in other words, will for a given load greatly increase the maximum unit oil film pressures.

Compensating for Deflection

If the longitudinal load distribution is to be uniform, it immediately follows that the journal will be deflected. For the sake of simplicity, and it is sufficiently accurate, let it be assumed that the journal acts as a cantilever beam carrying a uniform load, as indicated in Fig. 4. The dashed line in the figure indicates how the axis of the journal deviates from a straight line.

In order to have the load distribution uniform, it follows that the journal must be permitted to deflect as dictated by the uniform loading and that the bearing surface must conform to the warped surface of the journal. But these curvatures will vary according to the load carried and its direction. Neither of these two factors is constant, and even if they were, the warped surface presented by the deflected journal could not be duplicated commercially. It therefore follows that the design must be such that the pressure of the journal against the bearing will of itself cause the bearing surface to take a shape to compensate for the deflection of the journal.

With the problem established in its elementary terms, it becomes a simple matter to find the solution. In this instance, the solution was obtained by applying the relationship between stress and deformation. Thus, it is merely necessary to vary the thickness of the babbitt so that the deformation of the babbitt will conform to the deflection of the journal.

The simple **equation:**

$$d = \frac{f_e \times T}{E}$$

can be used to calculate the compression of the babbitt accurately.

The modulus of elasticity, E, ranges

between 1,000,000 for babbitt that has been cooled slowly after being poured, up to 2,000,000 for babbitt that has been chilled. The amount of compression d required to make the babbitt surface conform to the journal surface, the uniform unit load f_c, and the modulus of elasticity E are therefore known. The thickness T can then be calculated so that the compression of the babbitt will be the same as the deflection of the journal at the corresponding points. This design, which has been patented by the author, gives a simple construction, involving no complicated machining operations.

In the manufacture of plain bearings, some kind of anchoring groove is machined into the bearing shell and the surface of the shell is tinned. The shell is then preheated and the babbitt poured. As the bearing cools, the babbitt, on account of its higher coefficient of expansion, will try to shrink away from the steel bearing shell. The excess shrinkage of the babbitt over that of the steel is great. Tests have clearly shown that in almost every instance the bond between the babbitt and the shell is weakened, the babbitt in some instances tearing away from the shell.

Effect of Peening

It is this factor which makes it extremely detrimental to peen or roll the babbitt in the shell, a procedure which is still in common use. Because of the high internal stresses in the babbitt, particularly at the tinned surface where the babbitt fuses itself to the steel shell, the vibratory stresses set up by the peening are apt to cause the babbitt to break away from the shell. This tendency is greatly influenced by the brittleness of the tin. Tests have shown that the peened babbitt will tear away readily, whereas the unpeened babbitt in another portion of the same shell will adhere.

The danger of the babbitt tearing away from the shell is greater in large bearings than in small bearings. In the design of the bearings for gyroscopes it was extremely desirable to eliminate this condition. A rather unusual method was finally devised. After machining, the ends of the bearing were capped with steel plates, thereby forming a closed cylinder, as shown in Fig. 5. This cylinder, through a pipe connection, was filled with water and put under a hydraulic pressure of about 500 lb. per sq.in., sufficient to create stresses that were in the plastic range. This caused plastic flow of the babbitt, completely relieving the shrinkage stresses.

One of the most important things in the application of plain bearings is that an oil strainer and an oil cooler

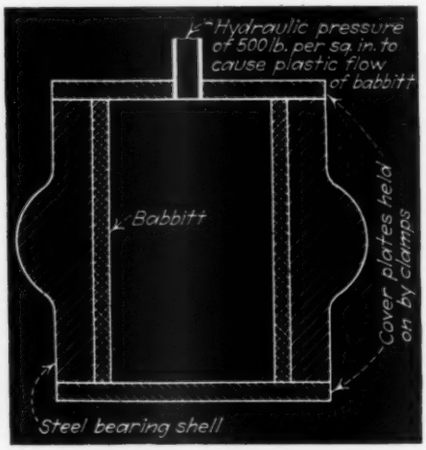

Hydraulic pressure of 500 lb. per sq. in. to cause plastic flow of babbitt
Babbitt
Cover plates held on by clamps
Steel bearing shell

Fig. 5—To relieve the shrinkage stresses in the babbitt, the bearing is put under hydraulic pressure to cause plastic flow

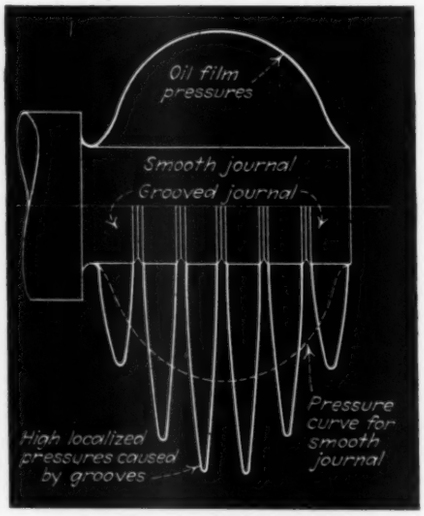


Fig. 6—Grit in the lubricating oil will wear grooves, resulting in high oil film pressures

be provided, although the latter may in some instances be dispensed with, depending upon the load and conditions involved. The strainer is used to take all grit out of the oil before it is returned to the bearing. The upper portion of Fig. 6 indicates the condition that exists when the journal and bearing surfaces are smooth. The pressure distribution curve is unbroken. If grit gets into the lubricating oil, circular grooves will soon be worn in the journal, creating a condition such as indicated in the lower half of the figure where the actual pressure distribution is shown by the full-line curves. At every groove there will be an almost complete breakdown of the oil film, the pressure will drop to virtually zero, and extremely high maximum pressures will be developed.

Oil Coolers

Sufficient attention is not always given to the question of lubricating oil temperatures. Up to a temperature of perhaps 100 deg. F., there is little variation in the strength of the babbitt metal. But beyond this temperature the ultimate strength continually decreases until the plastic state is reached somewhere in the neighborhood of 450 deg. F. These figures will vary considerably with the composition of the babbitt, but serve to give some idea of the effects of temperature upon the strength of the babbitt. At normal operating temperatures, the ultimate strength of the babbitt may not be more than perhaps 1500 lb. per sq.in., which is not much above the loads that are met when the allowable bearing pressure on the projected area is figured at 800 lb. per sq.in. That is, with an allowable load of 800 lb. per sq.in., the maximum unit pressure will probably be in the neighborhood of 1100 or 1200 lb. per sq.in., possibly even somewhat higher. It is therefore apparent that the temperature of the lubricating oil is of great importance. It must also be borne in mind that failure occurs when the temperature and pressure permit plastic flow, and that the unit stress at which plastic flow occurs decreases rapidly with increase in temperature.

Bearings that incorporate all of the refinements as set forth above probably approach the ultimate in both capacity and endurance. Such bearings have been in practically continuous operation over periods as long as eight years without any adjustments or repairs. Of course, this type of service is not required of every bearing, and it would be uneconomical to strive for such a degree of perfection for bearings in ordinary service. The refinements to be incorporated will in each instance be determined by the service conditions to be met and the expense that might be justified. These are, of course, questions that must be settled by the engineer, after studying a specific design.

PRODUCT DEVELOPMENTS

Streamlined, Air-Conditioned Aluminum Rail Car—Fifty Thousand Wiring Combinations—Die-Castings and Canvas-Cushion Wheels—The Brown Smoke-Density Meter—Humidity Control— Bakelite Valve for Concreting Oil Wells—Free Piston Air Compressor—Magnetic Locks

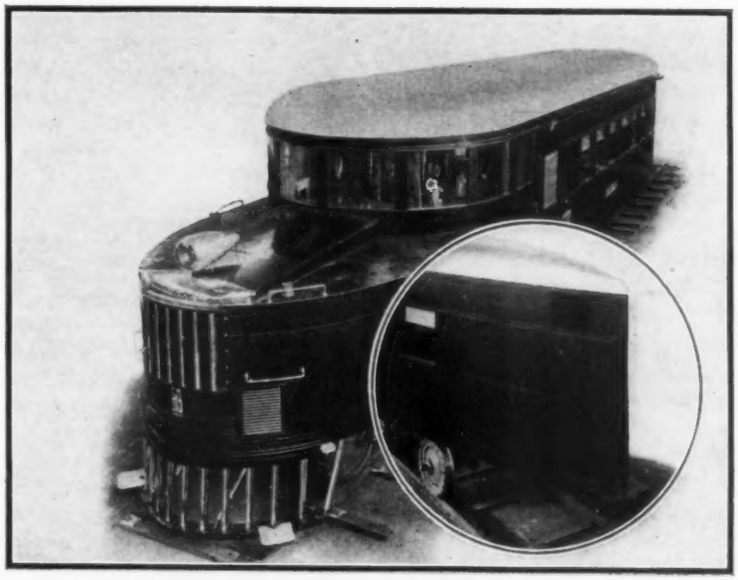
▸ Streamlined, Air-Conditioned Aluminum Rail Car

Powered with a V-16 gasoline engine, and designed for main-line railroad service, the Clark "AutoTram" was shown for the first time Dec. 5, at the Battle Creek plant of its builder, the Clark Tructractor Co. According to the engineers, the design of this new streamlined, air-conditioned aluminum rail car started with no preconceived requirements, either mechanical or esthetic. Preliminary studies convinced the designers that the best results could be achieved by following, in general, conventional car design so far as the frame was concerned, and by adopting automotive principles in drive mechanisms.

Accordingly, center-beam type of construction was adopted. The cambered center sill itself is fabricated out of 17-S aluminum alloy designed for a compressive strength of 450,000 lb., about 12 per cent above the requirements of the American Railway Engineering Association standard for much heavier construction than the AutoTram. The car itself is 60 ft. long overall, 10 ft. wide outside, has a clear maximum inside width of 9 ft. with headroom of 7 ft. 10 in., and is 11 ft. high above the rails. Total weight of the car empty is about 25,000 lb., of which 12,000 lb. is aluminum. The V-16 gas engine develops 150 hp. at 3,200 r.p.m. Conventional automotive transmission is used with universal joints; all gears in the driving train spiral beveled or helical; all shafts except those in the engine mounted in anti-friction bearings. The main engine, the generating plant and the blower are mounted in rubber. An auxiliary gas engine of 15 hp. drives everything but the car itself—the air-conditioning equipment, water and oil circulating systems, air compressor, etc.

Designed for a life of 1,000,000 miles, the car is insulated against drumming from the rails and operating mechanism and from outside noises. For strength a girder construction of side walls was adopted. Outside sheets are 17-S aluminum alloy; inside sheets 4-S half hard. Steel rivets are used throughout. To minimize drumming, special rubber-cushioned steel wheels of new design are employed. They weigh about 325 lb. each.

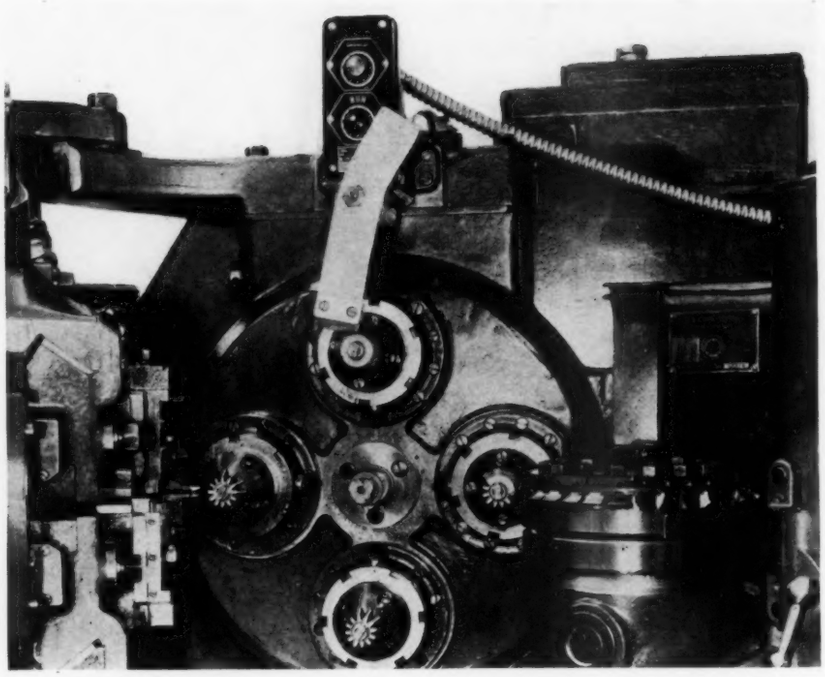
Dr. Felix Powlowski of the University of Michigan was retained as a consultant on the aerodynamic features of body design. The front end curves elliptically; the rear end tapers in a sharp parabola. With this design it is believed that power required at a speed of 60 m.p.h. will be only 50 per cent of what would be required for conventionally designed car. Even the cow-catcher bars are streamlined. Clark engineers estimate that the AutoTram can be built for about one-twentieth of the cost of comparable standard equipment.



Designed for main-line railroad service, the "AutoTram" is streamlined, air-conditioned and powered with a V-16 gas engine. Length, 60 ft.; width, 10 ft.; height, 11 ft.; weight approximately 25,000 lb., of which 12,000 lb. is aluminum

▸ Magnetic Locks

Many rather odd uses have been developed for the electromagnet from time to time, but perhaps one of the most unusual is the operation of a lock, or rather the simultaneous operation of a set of locks by the electromagnetic method. In the particular design referred to, manufactured by the Kingston Products Corp., every door of an automobile is locked si-



Engineers of Gleason Works have developed new generator for rough- and finish-cutting differential gears and pinions at one set-up, two operations formerly done on separate machines. Turret turns clockwise to roughing and finishing stations. Note inserted blade roughing cutter

multaneously by simply pushing a button located on the dash or at some other convenient point. The doors may be opened individually from inside, whether locked or unlocked, but cannot be opened from the outside, except by means of a key inserted in a master lock.

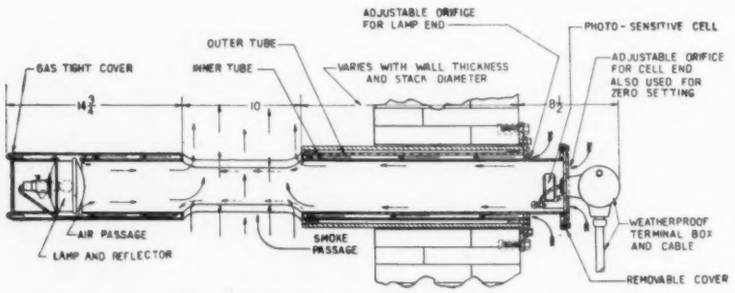
▶ The Brown Smoke-Density Meter

The engineers of the Brown Instrument Co. have developed a smoke-density meter which measures the density of smoke in flue gases by electro-optical means. As shown in the accompanying illustration, the principal units are the sampling tube containing a source of light and a photo-cell, a control panel, and an indicating or recording instrument. A novel feature of the equipment consists in having the source of light inside the flue, so that only one opening is required in the stack or uptake. This arrangement requires only a small space and simplifies installation. Another interesting feature is the sampling tube construction which prevents the accumulation of soot on the lamp or the photo-cell.

In this form of smoke meter a portion of the flue gas is made to pass between a source of light and a light-sensitive device. When the smoke in the flue gas varies in density, the amount of light falling upon the light-sensitive device also varies, and the resulting current variation from the photo-cell is transmitted to the indicating or recording meter. Since there is a definite relation between the current output of the photo-cell and the amount of light falling upon it, the meter may be calibrated in terms of smoke density.

The light source, which consists of a small electric light bulb at the focal point of a parabolic reflector, is placed at the inner end of the sampling tube. The bulb operates on 6 volts and is especially made for use in high temperatures up to 600 deg. F. It is operated at less than its rated wattage and accordingly has a life of several months continuous service before renewal is necessary. The reflector is chromium-plated, and both the reflector and the lamp are gasketed quite securely so that they will not come in contact with the flue gas nor with the air circulating around the assembly.

The light-sensitive device, located at the outer end of the sampling tube, is a form of photo-cell which does not require any auxiliary source of energy. No vacuum tubes or amplifying circuits are needed. The current from the photo-cell is sufficient to operate any of the standard models of Brown indicators or recorders, either the potentiometer or the millivoltmeter type. The sampling tube consists of two concentric cylinders, the outer one being 6 in. in diameter and about 4 ft. long, with orifices arranged in each one in such a manner that when this tube is inserted into the stack, flue gas will pass through the orifices. The cylinders are welded together at the orifices so that the annular space between the cylinders forms an air duct leading to the air outside the stack. The outer end of the sampling tube is provided with a weatherproof fitting from which a four-wire cable is run to the control panel.



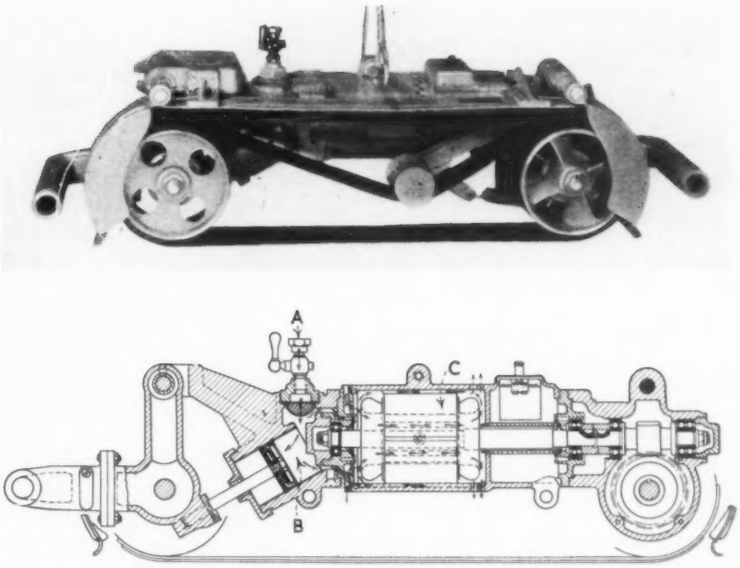
An electro-optical smoke-density meter wherein the light source and the light-sensitive device are protected from direct contact with flue gases

▶ Fifty Thousand Wiring Combinations

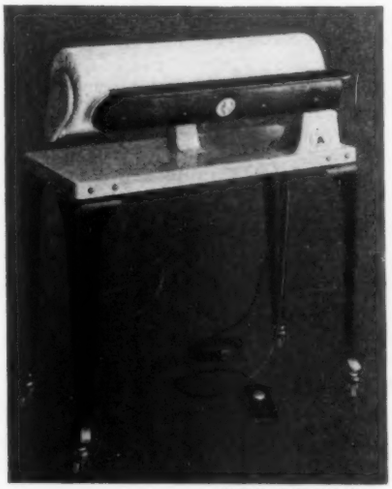
Using only seven styles of wall plates with spaces for interchangeable wiring devices, 59,244 different wiring combinations are possible with a new line of wiring devices now being molded by Auburn Button Works for Pass & Seymour, Inc. These units include a redesigned switch, convenience outlet, radio outlet, pilot and night light receptacle, bell push-button and blank inserts, all interchangeable. Constructed entirely of Bakelite with brass parts molded in

place, these units are so compact as to permit the use of as many as three of them with one single gang plate.

Being designed to fit into oblong openings in the wall plate and thus to give the appearance of an unbroken flush surface, these units are fastened to a metal holding strap which automatically spaces them to fit the hole in the plate. Holes in the strap accommodate the various units. At opposite ends of these holes, small slots are cut in the metal, two at each end. When a screwdriver point is inserted into these slots and twisted, the thin strip of metal between the slot and the hole is forced into a recess in the unit, gripping it firmly. The holding strap is fastened to the box with two screws in the same manner as old style devices are fastened. By the use of two and three gang plates, and the interchangeable units, any desired combination of one to six units is obtainable.



Compressed air serves double purpose in Hercules portable belt sander of The Buckeye Portable Tool Co. Air enters inlet *A*, operates belt tension cylinder *B* and cools high frequency motor *C*. Note leather belt supporting abrasive belt



Electrical Merchandising

New Westinghouse ironer employs principle of under-roll front feeding for cool and comfortable ironing. Mechanism concealed in roll; self-lubricating bronze bearings. Sleeve-board shoe and roll open at both ends. Built-in-watchman thermostat holds any temperature from 330 to 550 deg. F.

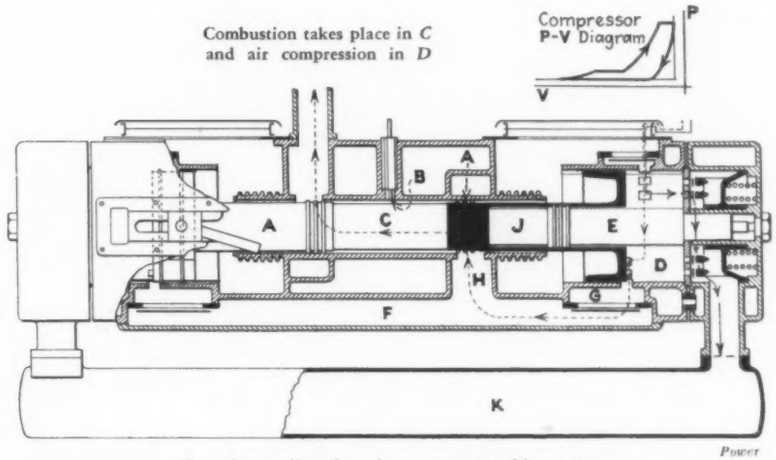
▸ Free-Piston Air Compressor

Invented by Marquis de Pescara, Paris, France, a free-piston oil-engine air compressor without connecting rods, cranks, valves, spark plugs or flywheel is coming into use in Europe.

Referring to the drawing, operation is as follows: The two opposed free pistons slide in and out in synchronism insured by a lever pivoted at its center and connected by side rods to the pistons. These rods do not normally transmit any power; their work is merely to absorb slight incidental variations in the operation of the pistons and to keep them in step. The oil pump, however, is operated by this mechanism. In effect, therefore, the pistons are entirely free of mechanical connections and act as engine pistons on the inner ends and as compressors on the outer ends.

All power is produced in space *C*, using the diesel two-stroke cycle. Fuel oil is injected at *B* in proportion to load. A coil spring (not shown) is cranked up for starting. The two pistons are driven together by the action of this spring. At the proper point explosion takes place and forces them out. This outward movement compresses air in the annular spaces shown at *D*.

During the first stages of compression, part of the air is by-passed through the plate valve *G* and acts as scavenging air, passing through *H* into combustion space *C* and out through the exhaust. As the stroke continues, the bypass port is closed, and the air pressure builds up for delivery to the receiver *K* from which it passes to the outside application. Compressed air locked in space *J* by the secondary fixed piston *E* acts as a cushion to insure return of the



Power

Free-piston oil-engine air compressor without connecting rods, cranks, valves, spark plugs or flywheel

piston *A*, regardless of the load on the compressor ends. All of these actions, of course, take place simultaneously at both ends of the machine, which is symmetrical in all respects except for the location of the scavenging and exhaust ports.

▸ Die-Castings and Canvas-Cushion Wheels

In the accompanying illustration of an assembled escalator step as manufactured by the Otis Elevator Company are shown the zinc die-cast step yoke, the canvas-cushion wheels, and the zinc die-cast step tread. Besides many other advantages of the zinc die-cast step yoke, no bearing liners are needed, the shafts rotating directly on the zinc which, under the conditions of operation, makes a good bearing surface.

In the construction of the treads, which are one-piece die-castings, the tread strips are cast hollow and later are filled with a plastic compound. This design has shown far greater resistance to wear than any of the many other constructions that have been tried.

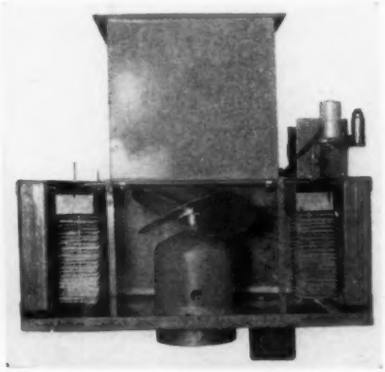
Of course, the use of canvas-cushion wheels is mainly for the purpose of eliminating noise, an extremely important factor in the design of this type of equipment.

▸ Humidity Control

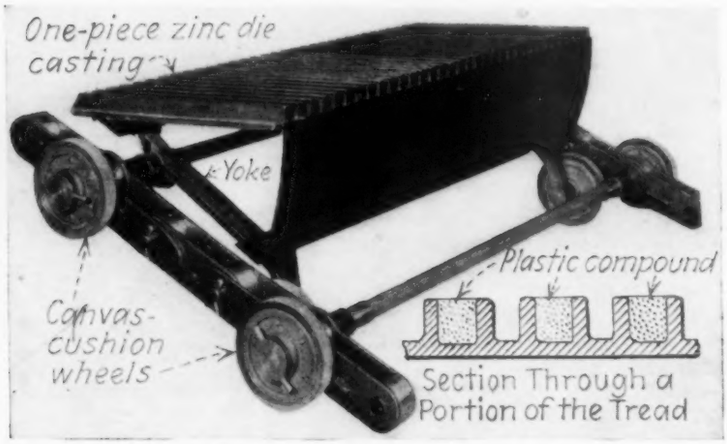
In the "humifilter," the engineers of General Electric Co. have developed a device which will circulate, filter, and humidify air in a home without the use of a duct system. Using electric power at the same rate as a single incandescent lamp, the device is capable of producing a complete change of air in the lower part of a house in 40 min.

Having an evaporating capacity which will supply an adequate amount of moisture to homes with a volume not exceeding 50,000 cu.ft., the humifilter has a filtering capacity which will take care of a volume of about 15,000 cu.ft., or a home with six to eight rooms on the lower floor. The device is installed in the first floor of a home and discharges a gentle flow of air through the floor grill. The air is taken from the basement and passed through a filter which removes dust suspended in the air. It then passes through a humidifier which makes use of hot water to facilitate evaporation. The water is heated by a small amount of steam supplied by the existing boiler.

Cleaned and humidified, the air then passes through the discharge grill. The circulation is produced by a quiet, elastically-mounted fan driven by a small motor. The air is brought back to the basement through a return grill at the far side of the house. A "humidistat" measures the relative humidity of the air and automatically controls the amount of moisture evaporated in the humifilter.



"Humifilter" with cover removed to show the elastically mounted fan and the humidifier units



In this escalator step, the yoke is a zinc die casting, as is also the tread. The canvas-cushion wheels are used because they are noiseless and can stand up under the severe service conditions

▸ Bakelite Valve for Concreting Oil Wells

With molded plastics entering almost every phase of engineering activity on earth and above the earth, it is not so surprising to discover that canvas-bonded Bakelite is taking an important part in sub-surface oil field operations. As shown in the accompanying illustration, the engineers of Larkin Packer Co. have designed a device for placing concrete wherever oil-well drillers run into quicksand or other loose and troublesome formations. Briefly, the device consists of a spring-held valve, a "float shoe" and a "shoe guide" all molded by the Chicago Moulded Products Corp. out of canvas-bonded Bakelite.

Canvas-bonded Bakelite valves, "float shoes" and "guide shoes" are vital elements in a device for sealing oil wells against quicksand. Through them concrete is forced until back pressure indicates that quicksand is blocked. Bakelite parts replace aluminum for reasons noted in the accompanying description

When the driller runs into quicksand, he withdraws his drill bit and lets down a 7-in. casing with the valve, float shoe and shoe guide screwed into place. He then forces concrete through the valve and out the shoe guide until back pressure shows that the quicksand is blocked. The concrete is then allowed to set for 48 hours; the drill bit is lowered through the casing and the Bakelite drilled out as if it were a part of the earth formation. Aluminum parts are frequently used for this service, but drillers who have used the new valve report that the phenolic resinoid is not so likely to clog drill bits.

"POWDERED METALS"

From the Designer's Point of View

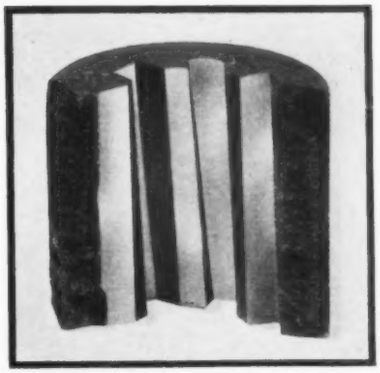
The art of using "powdered metals" in the modern sense begins, not with bronze powders for gilding picture frames and flag poles and for other more or less decorative uses, but with tungsten—powdered, compressed, sintered, drawn into wire and coiled for electric light filaments (*PE*—Oct., 1932, p. 405—*Metal Progress,* July, 1932). And during the past eight years we have seen powdered metals evolve from scientific curiosities into engineering materials in daily use. One make of automobile uses over 80 powdered metal bearings and parts; tungsten-carbide cutting tools are in every shop; copper-graphite brushes function in countless motors and dynamos; powdered metal welding electrodes are standard.

Without going too deeply into manufacturing processes, practically any metal, such as copper, iron, nickel, chromium, tin, zinc, silver or molybdenum can be produced electrolytically to pass through 200- to 300-mesh screens, compressed in dies at 2 to 250 tons per sq.in., and sintered to weld or alloy the particles. It is significant that on subsequent breaking tests the particles themselves almost invariably let go before the welds.

Processed in reducing atmospheres, such as hydrogen or hydrogen and nitrogen, metals of almost unbelievable purity can be obtained—copper free from cuprous oxide, for example. Two or more metals of widely varying melting points, impossible to alloy by orthodox melting methods, can be alloyed. Metals and non-metals, like tungsten and carbide, copper and porcelain, copper and alundum, can also be combined as by no other known process.

Density Varies with Pressure

Obviously the density of compressed powdered metal will vary with the pressure applied in the dies and with subsequent reworking, restriking or rerolling. Taking copper as an example, 2 tons pressure will give a product having a density of approximately 4.2 as against a normal density for cast copper of 8.40; with 250 tons, a density of 8.3 may be obtained, and still higher densities with repressings after heat-treatment. Porosity, as in so-called "oilless" bearings, may vary widely in accordance with striking pressure. In one patented process porosity in bearings is achieved by compressing a mixture of powdered copper, tin, graphite and a volatile salt. In the subsequent sintering or heat-treatment, the volatile material is driven out, leaving voids for oil. Satisfactory bearings for heavy duty may contain from 30 to 40 per cent oil, by volume.



Pressed out of powdered metal this accurate rifled nut requires no machining

Naturally the designer will leave manufacturing processes to the production department, but it might be well to interpolate that in more cases than generally realized, the finished piece can be brought within exceedingly close limits by restriking or coining in a sizing die—limits in some cases as close as 0.0005 in.

Since it is possible to hold close limits, the higher price of powdered metals may frequently be more than offset by savings in manufacturing. Losses are small as compared with those resulting from the many operations in conventional practice.

A case in point is the rifled nut shown in the illustration. Former practice called for the cutting off, drilling and rifling of bronze rod stock—total cost over $1.00 per piece. With powdered metal all machining is eliminated, and the total cost is $0.63 each, including a charge of $0.15 each for die depreciation. Two thousand pieces will pay for the die, after which each piece will cost but $0.48 for the remaining life of the die.

Future developments in the art of powdered metals should be watched closely. Already it is being found possible to roll stainless steel strips out of powdered metal billets, giving several advantages. In the first place the chromium and nickel content of the alloy can be held more closely than by conventional furnace practice; in the second, the strips are more homogeneous; in the third, powdered metal billets are easier to roll due to initial lower density of the billet.

Right now considerable work is being done on the application of powdered metal parts in the electrical industry and in the building hardware industry, in fact in several industries where quantities are large and mass production of high strength parts is requisite.

Physical Characteristics

The designer may very reasonably ask at this point, "What about the physical characteristics of units made of these powdered metals?"

Though the answer is not so simple as it might be, it may be said in general that owing to the purity of the powders—and to the fact that there is no limitation on the number of repressings, heat-treatments and reworkings—tensiles, hardnesses and the like may be made to duplicate those achieved by conventional methods, and frequently to exceed them. After all, the highest tensile ever achieved in a wire is that of tungsten—650,000 lb. per sq.in.—and that wire was drawn from a powdered metal billet.

[Editor's Note—*Material for this article was furnished through the courtesy of Charles Hardy, president, Hardy Metallurgical Co., pioneer in the development of powdered metal.*]

Simplified Machine for an Intricate Process

Valveless pumps, solenoid clutches and other new mechanisms were developed for this simple and compact type-casting machine for office use

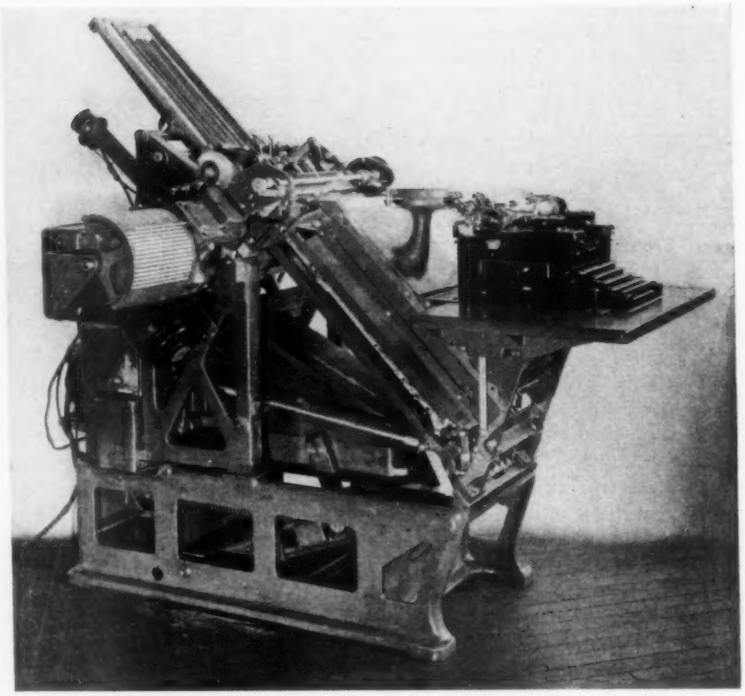
▼

In the operation of simplified printing machines for office use, such as the Multigraph, setting the type is both costly and time-consuming. The need of an automatic machine for doing this work has been evident. But considering the complexity of the Linotype and Monotype, it appeared that any design of type composing machine would, of necessity, have to be a large and intricate device. What was needed was a simple compact machine, relatively inexpensive—one that could be operated in an office by any typist. That was the problem given to the designing engineers of the Castype Corporation, a company organized for the sole purose of developing and marketing such a machine.

Principle of Operation

At first the thought was to have a typewriter operate a mechanism that would select individual matrices letter by letter, set them in a line and cast the metal slug. Such a machine would largely follow the principles of the Linotype. Therefore, it would have to incorporate all of the complex mechanisms required for sorting and redistributing the matrices after casting the line. This in itself ruled out all possibility of developing a simple machine using the Linotype system. Fundamentally new principles and new mechanisms would have to be developed.

After much study, the engineers hit upon the idea of using matrix strips



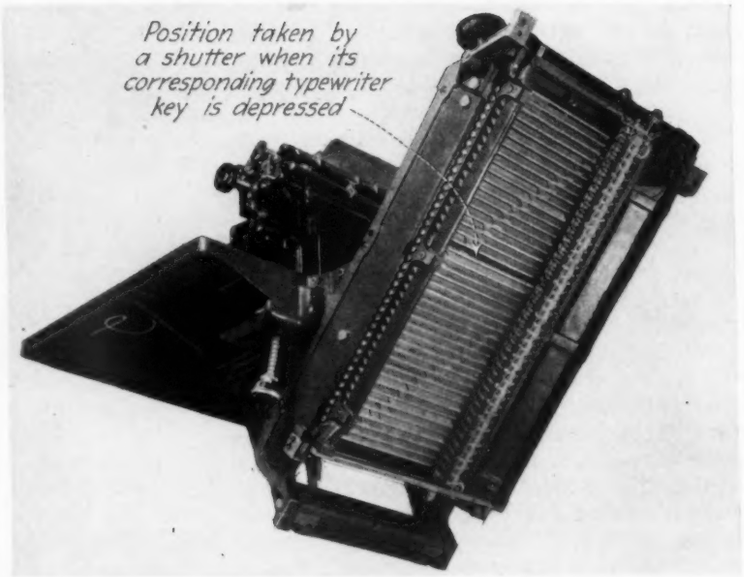


Fig. 1—(Above) Lines of cast type are automatically mounted in the type cylinder of the printing machine

Fig. 2—(Below) Selector head section showing the shutter assembly with the plunger carriage at the extreme right

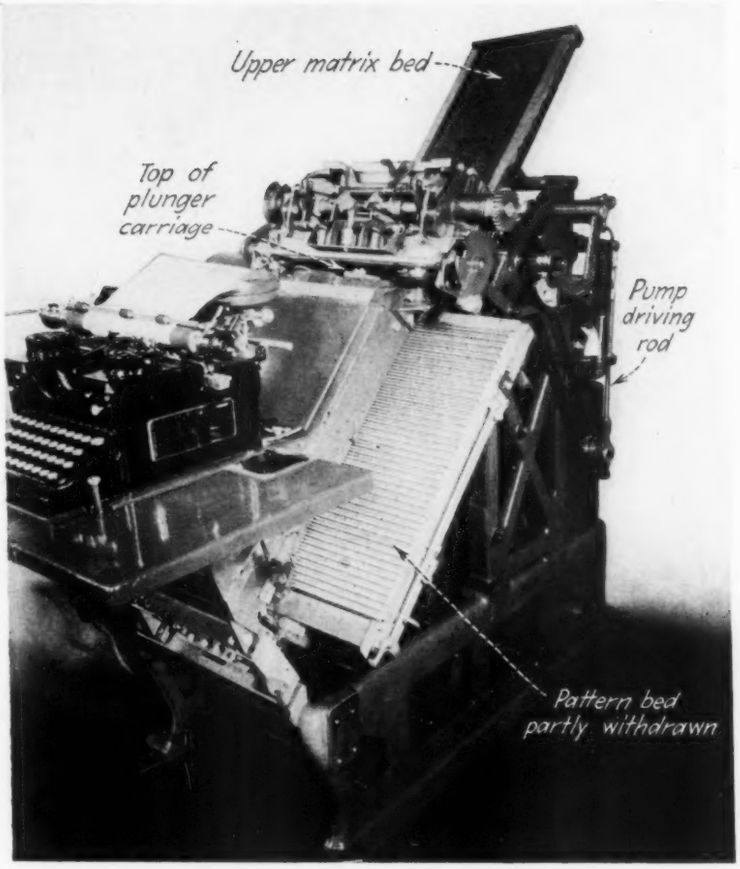


Fig. 3—Pattern bed partly withdrawn to exchange for another to accommodate a larger or a smaller size of type

made of brass. Along one edge of the brass strip 84 notches were cut, forming the mats in the slug to be cast and into which all of the characters of the typewriter were to be depressed. As finally developed, the matrices are about 2 ft. long and $\frac{3}{4}$ in. wide, the thickness being determined by the size of the type. All the matrices are exactly alike, the sequence of the characters being dictated by the typewriter keyboard. The matrix strips are placed side by side in a magazine, one strip for each horizontal typewriter space. In the machine illustrated, there are 90 matrix strips for casting a slug of pica-size type, 9 in. long.

Method of Operation

Operation of the machine is simple. Under each of the 42 keys of the standard typewriter is a bell-crank, movement of which operates one of 42 horizontal shutters spaced $\frac{1}{2}$ in. apart. Depressing a typewriter key turns its corresponding shutter much in the same manner as when opening a single louvre in an ordinary window shutter. Below the shutter is a carriage on which are mounted 42 small plungers, one for each louvre of the shutter. This carriage is moved across the machine by being connected to and controlled by the typewriter carriage. In Fig. 2 it can be seen how the carriage plungers operate in relation to the shutter.

The pattern bed is made of punched longitudinal and cross strips of stainless steel, interlocked to make an accurate and rigid honeycomb bed as shown in Fig. 3. Into the openings are fitted the stops whose only movement is up or down. Every stop in one row across the bed corresponds to a character on the typewriter keyboard. These rows might be considered as being in pairs, the upper row of each pair corresponding to the lower case letters and the lower row corresponding to the upper case letters or the characters that are obtained when the shift key is depressed. Thus there are twice the number of rows of stops as there are plungers and shutters. When the typewriter shift key is depressed, the plunger carriage is shifted correspondingly thereby, bringing the plungers in line with the lower of the pairs of rows of stops.

The plunger carriage moves horizontally in synchronism with the typewriter carriage, thereby positioning the carriage with respect to the columns of stops. A continuous cord, rigged in the same way as the cord on the sliding straight edge of a drawing board, keeps the plunger carriage axis perpendicular to the shutters. This simple device made it unnecessary to design the plunger carriage as a rigid cantilever, which would have added much weight. Also, with the cord device the carriage roller and roller guide are relieved of all loads other than merely supporting the weight of the carriage. The cord is phosphor-bronze wire.

Casting the Type

When a line has been written on the typewriter, a corresponding pattern of stops has been set up in the pattern bed. The typist then taps a key which starts a cycle of automatic operations. The pattern bed moves back about $\frac{1}{8}$ in., putting the depressed stops in the path of the matrices. At their lower end, each of the matrices is attached by a sort of spring clip to a pull-bar which pulls the whole bed of matrices downward, underneath and parallel to the plane of the pattern bed.

Attached to the lower end of each matrix strip is a steel head with a small projection or heel on the upper edge which engages in a slot in the bottom of the pattern bed to keep the strip in line. When the heel meets the depressed stop, the matrix bar lets go of the pull-bar. With each matrix positioned by its stop, the characters in a line directly over the mold are the same as the characters in the line that has been typed. An aligning bar then drops into notches on the back of the matrices, lining them up accurately. This accomplished, the pattern bed immediately moves forward again, clearing the bed by raising all of the stops simultaneously. This permits the typist to resume writing. Up to this point in the cycle of automatic operation, about two seconds is required. Thus, the typist need pause only two seconds between lines.

The balance of the operation of the cycle includes squeezing the matrices, raising the mold and pot against the matrices and pressure bar to form a secure lock-up, the sudden

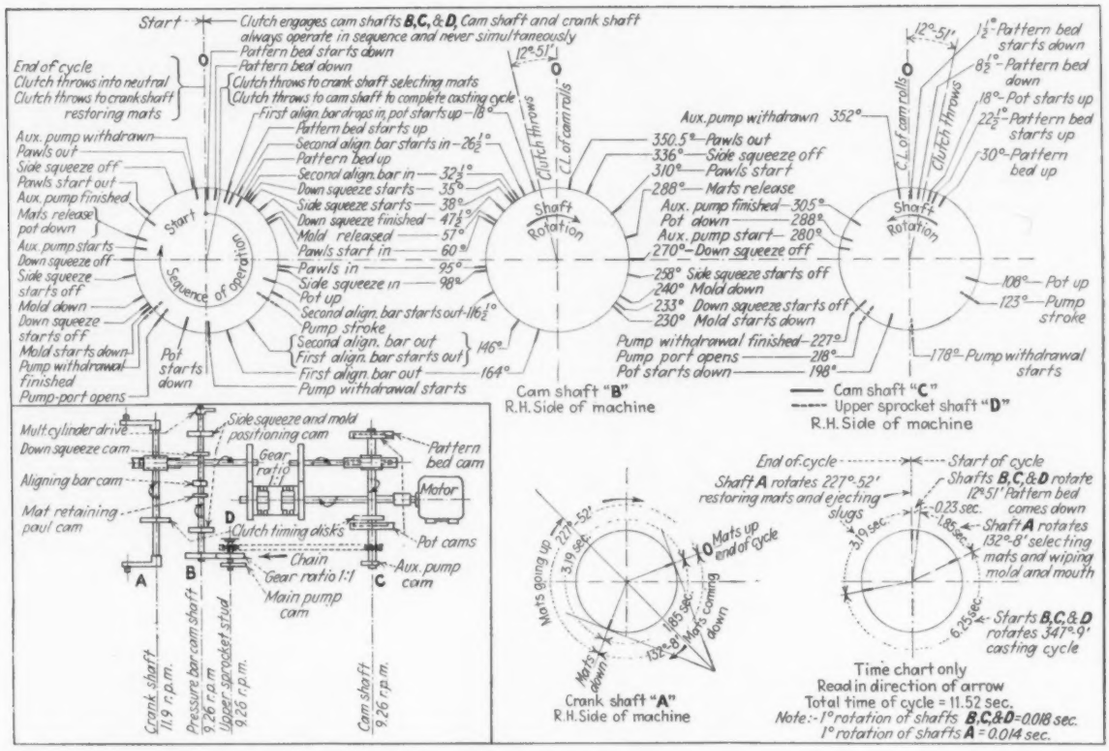


Fig. 4—Lower left-hand corner shows diagrammatically the arrangement of shafts and drives which are lettered to correspond to the letters used in the charts of the cycle of operations

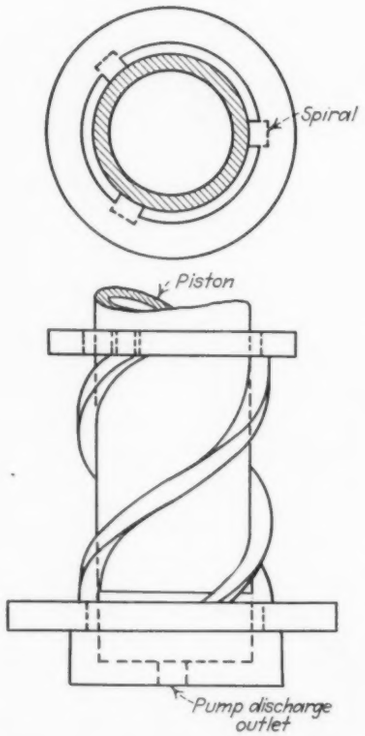
pumping of the hot metal into the mold, withdrawing the pumps, the pot and the mold, and the ejection of the slug of finished type on the side of the machine while the matrices are returning to their upper or normal position. The total cycle of automatic operations require about 12 seconds.

A detailed description of all of the mechanisms, gear drives and cams that comprise this machine would require much space. For those particularly interested in the details as to sequence of operation and the arrangement of shaft and gears and cams, the accompanying illustration, Fig. 4 will probably suffice. Of more general interest are some of the details of the parts, constructions and materials used.

Machine Drive

It will be observed in Fig. 4 that there are two distinct sections in the machine drive. These sections operate successively, the one remaining stationary while the other is moving. The ¼-hp. driving motor with built-in speed reducer runs continuously so that there will be no time lost in waiting for the motor to come up to speed. The clutching problem was then to devise something that would quickly throw the clutch into engagement to drive one section of the machine and after this portion of the cycle of operations had been completed would cause the clutch to shift over to drive the other section of the machine, and then automatically return to the neutral position. All this was to be accomplished with a minimum loss of time and in the simplest manner possible. A solenoid-operated clutch solved the problem. Quick action, no complicated linkages, simplicity and compactness were thus obtained. A timing cam operates the control switches.

Fig. 5—In this valveless pump, which operates submerged in the molten type-metal, the piston is guided by the spirals which wipe off any dross. The piston is shown in its extreme up position



Melting Pots

One of the units that presented numerous problems was that for molding the slug. Above the matrices and directly over the mold is the pressure bar which takes the pressure at the time of lock-up. Below and behind the mold is a movable pot, containing the molten type metal, and two pumps for better distribution of the pressure on account of the long line that is cast. Behind the movable pot is a larger one, a reservoir from which some metal is transferred into the movable pot each time a cast is made. Behind this reservoir is the electrical distribution box containing the switches, circuit breakers and other controls. The pots are heated by Chromolax units, the temperature being automatically controlled by

thermostats. The mold jaws are made of nitralloy so that there will be no warping on account of the hot metal. To prevent freezing of the metal in the mouth of the mold, Chromolax heating units are provided.

Pump Drives

In view of the fact that this machine was to be used in offices and would not receive constant and expert attention, particular care had to be taken to make it fool-proof. One factor that had to be guarded against was the possibility of damage to the machine should it be put into operation before the type metal in the pot and reservoir had become fluid.

In the accompanying Fig. 7 is shown diagrammatically how this problem was solved. When the cycle of operations has been completed, the position of the cam is always as indicated in the figure. Should the machine be started with the type metal still solid, the only force that can be transmitted to the pump will be that arising from the compression of the spring which, of course, can do no damage.

It will be observed that the work of pumping is done by the energy stored in the spring rather than by a direct force transmitted from the motor. This same idea has been used at a number of other places in the machine. That is, the stored energy in the spring does the work. This idea has much to commend it. It makes is possible to limit to a definite amount, as determined by the spring adjustment, the force actuating the mechanism.

Again keeping in mind the necessity for fool-proof construction, much time was devoted to the development of a hot metal pump that would not require frequent attention. Usually, such pumps give trouble, dross causing the plunger to stick. In Fig. 5 is shown diagrammatically the patented pump that was developed. The spirals serve to wipe the piston clean on every stroke. There are no valves.

The ¼-hp. geared head motor, operating at 1,750 r.p.m., drives the main shaft at 250 r.p.m. The worm reduction, as shown in Fig. 4, reduced this speed to about 9 and 11 r.p.m. for the two sections of the machine. With such low speeds and low unit bearing pressures, oilless bushings are ideal and therefore used almost entirely. In a few places where the speed and loads are relatively higher, wool-packed lubrication is used. It must also be considered that the operation is extremely intermittent, only one revolution being made by both the front and rear main shaft for each cast.

In the design of this machine, great care had to be exercised in order that the force required to depress the typewriter keys would not be too great. Therefore, the bell-crank, shutters, plungers and stops had to be designed for minimum weight and, what is probably more important, a minimum moment of inertia. In such a design, where much of the motion is rotary rather than linear, moment of inertia rather than mass is the dominating factor effecting the forces required to produce the motion. For this reason, short bell-cranks and minimum throws were used, all of the parts being stampings or wires. All the stampings are cadmium-plated. The work of friction is minimized in the usual manner by using small diameter bearings. The only appreciable amount of friction is that necessary to hold the stops in the pattern bed in their upper position. For this purpose, flat phosphor bronze springs are used, the flat springs bearing against the sides of the stops, thereby holding them in the "up" position by friction.

Many further details of the design of this machine are shown in the accompanying illustrations. Because this Castype machine is designed for office use much attention had to be given to appearance and quietness of operation. The motor is rubber mounted. Impact between metallic parts is avoided wherever possible. And throughout the design the first thought always was to devise the most simple fool-proof constructions so that any person could operate the machine and yet could not damage it.

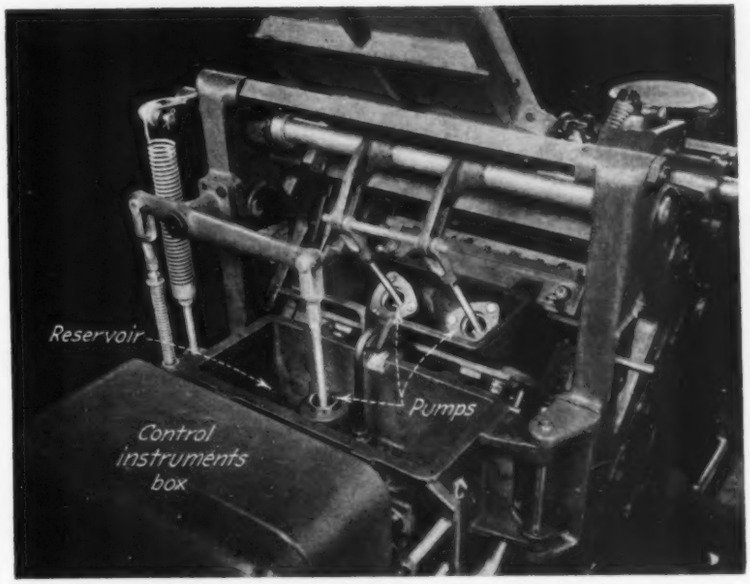


Fig. 6—Close-up of the two melting pots, empty and without covers or insulation. In the foreground is the case containing the thermostats and controls

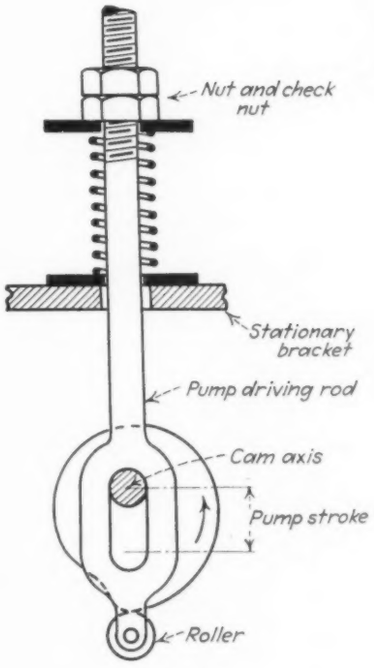


Fig. 7—(Left) At the end of each cycle the pump cam remains in the position shown here. The work of pumping is done by the energy stored in the spring

Retaining and

ADAM FREDERICKS

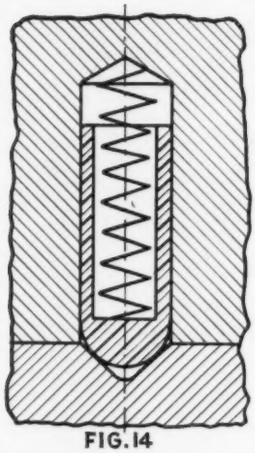


FIG. 14

Fig. 14—Instead of a ball, a hollow plunger is used which accommodates the spring. The end is hemispherical.

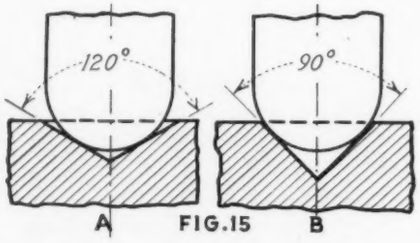


FIG. 15

Fig. 15—At *A* is shown the usual 120 deg. conical spot made with a drill. At *B* is shown a 90-deg. spot which gives a more positive seat, one which will not permit the plunger to disengage as readily and which is preferable when considerable vibration is encountered.

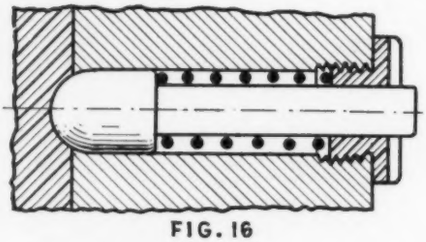


FIG. 16

Fig. 16—The plunger is turned down slightly smaller than the inside diameter of the spring which gets its other bearing against the threaded plug, the hole in the plug guiding the stem of the plunger.

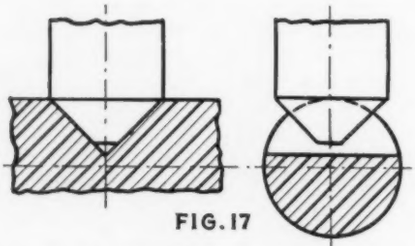


FIG. 17

Fig. 17—Instead of a hole, a slot is milled across the rod. The plunger being conical, it is obvious that only line contact is obtained.

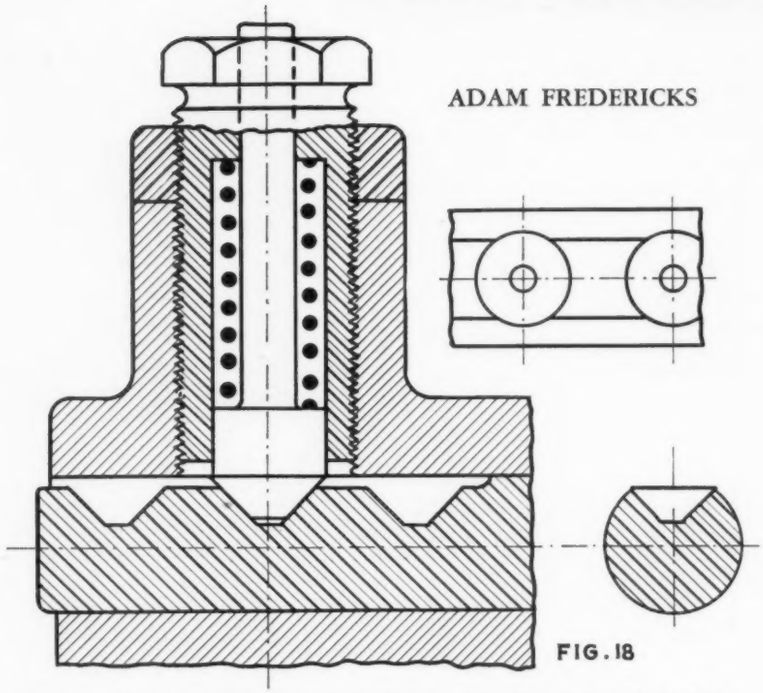


FIG. 18

Fig. 18—The spring tension may be increased or decreased as desired by the long hollow threaded plug, which is then locked in position by means of the check nut. In this design, the rod is flattened and the locating holes which are truncated cones in shape, are machined into the flat surface.

Fig. 19—Below to the left, the round plunger is flat milled to a 90-deg. included angle and prevented from turning by pin *A* engaging milled slots in the threaded plug. In the end view shown at *B* it can be seen that if the spring tension is to be adjusted, at least a half turn must be given in order that the flattened point will coincide with the slot in the rod.

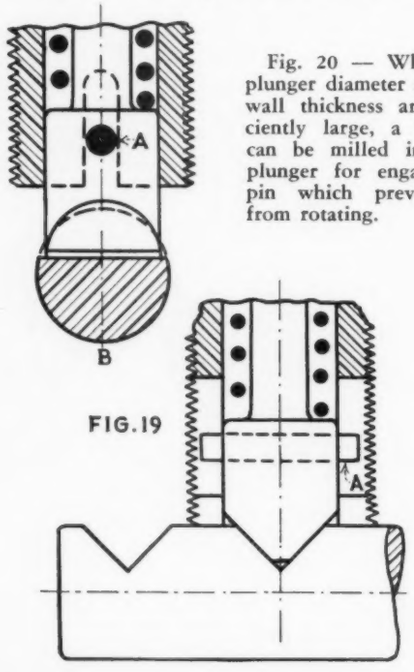


FIG. 19

Fig. 20 — When the plunger diameter and the wall thickness are sufficiently large, a keyway can be milled into the plunger for engaging a pin which prevents it from rotating.

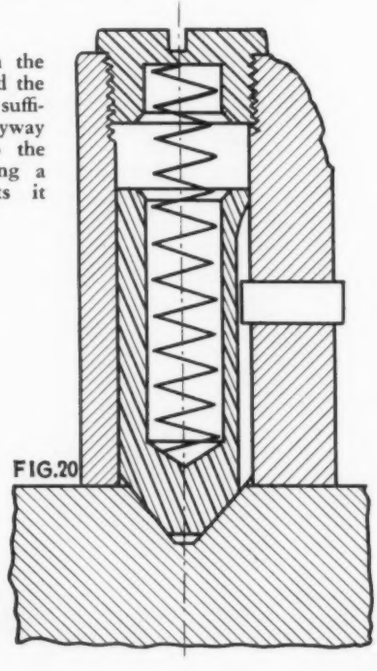


FIG. 20

Locking Detents—II

Thirteen typical constructions to supplement the thirteen appearing in the December number. It is not too much to say that at least one of them will be found applicable to a given set of conditions

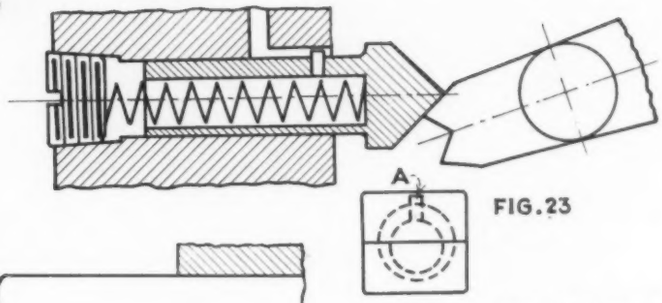


FIG. 23

Fig. 23 — Here is shown a square-headed plunger with its body turned round to accommodate the spring in an eccentric hole, thereby giving a support to the pin *A* which acts as a key.

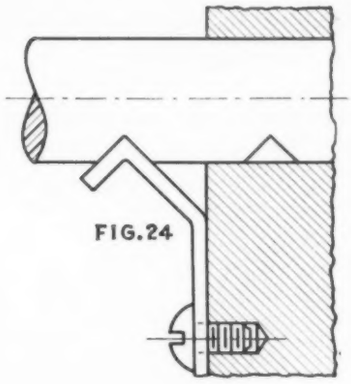


FIG. 24

Fig. 24—Probably one of the simplest yet most highly efficient forms of detent is merely a flat spring bent to a 90-deg. included angle and seating in Vees milled in the rod.

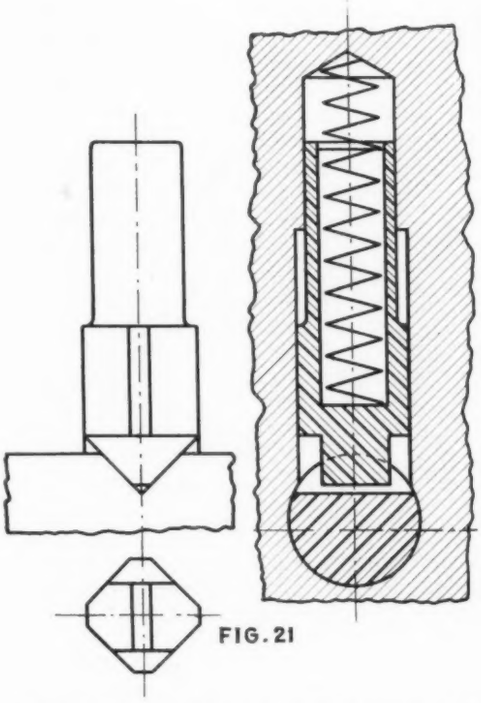


FIG. 21

Fig. 21—The plunger is milled square with round corners and the hole partially broached, doing away with the necessity of a key. The point is flat milled.

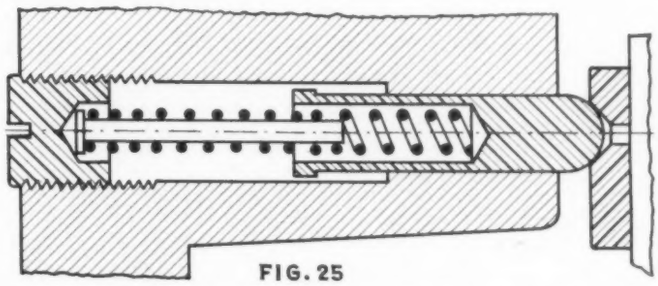


FIG. 25

Fig. 25—With a long spring and a fairly short plunger, a common flat-head wire nail can be used to support the spring against buckling. The spring also fits closely into the plunger hole to gain support and the plunger is flanged at its upper end to prevent its slipping through the hole.

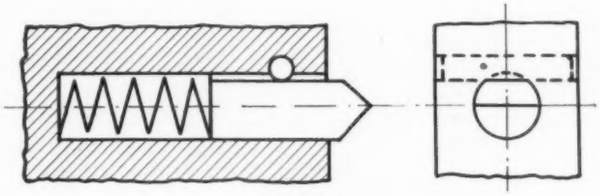


FIG. 22

Fig. 22—Sometimes the plunger can be milled with a flat which bears against a pin as shown in the end view to the right, thus preventing the plunger from turning in the hole, which design is particularly suitable for solid-type plungers.

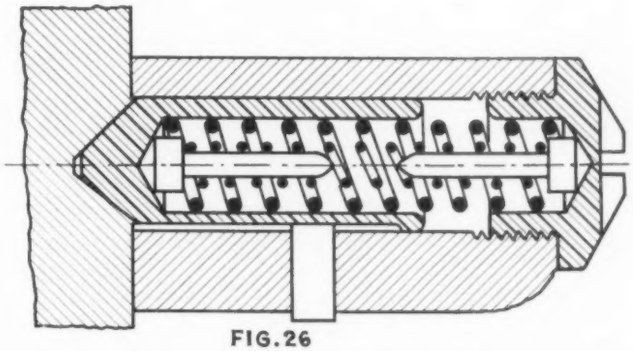
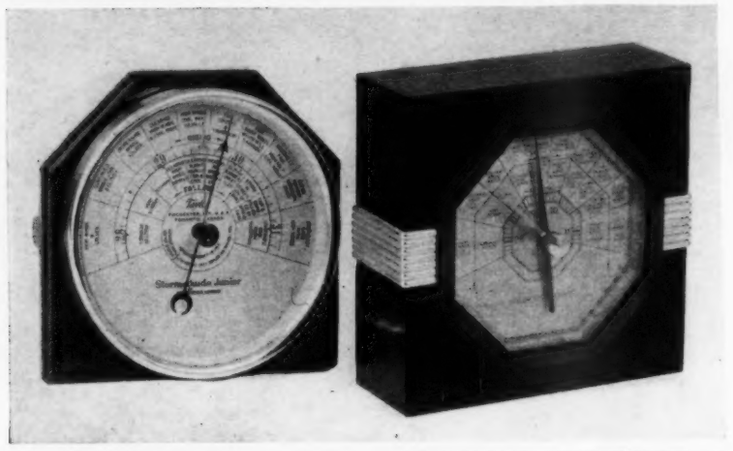


FIG. 26

Fig. 26—This design is similar to Fig. 20. When confined to a small diameter, a smaller spring is placed within the larger. Using a $\frac{5}{16}$ O.D. outer spring, 25 per cent spring tension can be gained by the addition of the inner spring. The larger one has a sliding fit in the plunger and screw plug holes. Two guide pins, the heads fittings closely into the larger spring, keep the inner spring central and free from buckling.



From left to right, the old Taylor Stormoguide and the new as "redesigned for the eye" by Walter Dorwin Teague, industrial designer

Designing for the Eye

FRANKLIN E. BRILL
General Plastics Inc.

"We are still human and our minds cannot be mechanized. For this reason many a product outsells a more mechanically efficient competitor, merely because of a more subtle curve, a more pleasing line or a fresh new contour."

It is a curious fact in product engineering and design that the more tightly an engineer is tied down by limitations of material and function, the better-looking work he does. When rigidly inhibited he produces the steamship and the suspension bridge—masterpieces of beauty. But when given a little leeway from the strictly functional and told to make something "attractive," the result is all too often an ugly household appliance or an utterly drab machine.

We who place raw materials at the disposal of the engineer are naturally disappointed at the lack of thought put into the average design. Especially we producers of the new "three-dimensional synthetics"—plastics, alloys, etc.—are discouraged at the way our inventions are warped into feeble imitations of the old materials we are trying to displace, or worse yet, manipulated into old ugly forms instead of the fresh new ones now possible.

We are tired of imitation and substitution. We are tired of dishonest designing—tired of seeing "marbleized" sheet plastics, and "woodgrained" aluminum violins which-can't-be-told-from-real-ones. We are tired of mixing brown or red molding powder to produce a deceitful mahogany or walnut, to enable incompetents to cover up their lack of design-training.

Frankly, we begin to feel the need of new brains and new feelings, less steeped in the ruling pen and the blueprint, more sensitive to style, line, color, and the subtleties of three-dimensional form—brains that can be trusted to be at least honest when they depart from the wholly functional. We want people to think of our new synthetics as basic materials in themselves, not something-just-as-good.

When we plead for æsthetics in product design, we are not moved by any reformer's desire for a better world, but by an utterly selfish motive—profits. Sitting on the sidelines as we do, we see innumerable cases of good use and mis-use of our materials passing in review. We see poorly-designed molded products which gather dust on retail shelves and convince both the sponsor and other manufacturers that molded plastics lack appeal. The immediate loss is the manufacturer's, but our industry also suffers. On the other hand we see molded products designed by æsthetically-trained artist-engineers schooled in the proper use of line, form, texture and color, which have that certain magic appeal that rolls up impressive new sales records. Such products help both the sponsor and our industry immeasurably.

Perhaps the word "æsthetic" is an unfortunate choice, since it connotes impractical artiness and other things odious to the average industrialist. But it's about the only word to describe an appreciation of the importance of visual mental impressions, to which the technician pays very little attention. Most of the rules governing the choice of color and form are being violated daily in the most flagrant way in our factories and drafting rooms. With amusing optimism we are producing product after product which no self-respecting eye can look upon with any degree of comfort or interest. We assault the consumer's eye with colors whose unmatched wave-lengths produce discords and dirges which, if perpetrated in sound, would drive every cash customer from the concert hall. We drag their eyes over lines and contours thrown together without the slightest regard for optical nerves and their laws, until the consumer turns from our brain-children with either a subconscious shudder of revulsion or a yawn of utter boredom.

Need for Trained Design

Of course, the product engineer is not wholly to blame for the visual mess with which we have surrounded ourselves. Most of the progressive ones are well aware of the need for trained design. The guilt really rests with Industry-at-Large, with its

short-sighted niggardly policy of designing catch-as-catch-can, and its refusal to recognize industrial art at all until a few years ago. Fabricators are forced to do their own designing, and too often the manufacturer's own mechanical draftsmen are dressed in smocks and told to put a little art in the old blue-prints. As a result, two-dimensional thinking—fathered by long years of poring over blueprints—is all too often adapted to three-dimensional products, and attempts to be "modern" resolve themselves into a meaningless series of zigzag lines—as dishonest a device for covering up feeble design as the swirls, carvings and fussy ornaments of the Rococo and Victorian ages.

Not for Average Designer

Three-dimensional industrial design for consumer products is much too difficult an art to expect the average engineer to learn. If the estimates of authorities are true that it takes a writer ten years to learn to juggle words and sentences pleasingly and correctly, then it must be equally true that proper combination of the dozen or more distinct types of lines, the half-dozen distinct types of masses, and the almost innumerable color and texture variations, takes fully as long to learn. Perhaps, like music, design is something that certain individuals simply cannot comprehend. At any rate, it is interesting to know that there are but a dozen product design consultants in the country today who have definitely proved their value to industry by increasing sales, cutting manufacturing costs, or doing both.

This small group of trained and tested people constitute a new type of business individual. They have coldbloodedly combined Æsthetics with Industry with but one definite objective—to increase sales. They have divorced themselves entirely from Art for Art's Sake, and are concentrating on the more tangible task of reconciling Art with the Machine. They are succeeding. They are producing such notable successes as the Taylor Stormoguide, a fresh new form that increased sales over 65 per cent in the first year, and the Hammond Junior electric clock which from the viewpoint of sales alone is probably America's most successful timepiece.

Why these new designers and their new designs are so successful is not easily explained. Perhaps it is because their designs are extremely simple, and are restful to the eye because all useless ornament and decoration is discarded. Perhaps it is because their designs are scientifically balanced. Then again, perhaps it is the utter honesty of the objects which we like.

Honesty in product design is much more difficult than it might seem. The past has a strong hold on us, and we love to revert to the good old days, and their old familiar forms, and we love to make our new machine-age products look cleverly old and mellow. But we can't do it. We can't go on making our molded-by-the-million clock cases look like carved models of old cathedrals. The age of craftsmanship is definitely dead. Mass-production is a household word, and our imitations of medieval handiwork are just plain ridiculous.

Humidiguide recently designed by Teague as a companion to Stormoguide

We're designing directly for the machine now. We've entirely eliminated the potter, the metal-smith and the weaver, and the machine translates our new design just as beautifully and a million times more productively. We're designing for the masses too, and the connoisseur of the old days is merely a memory, ignored in modern merchandising plans. At last we are free, liberated from old forms by the machine, and if our designers can't capitalize on the new forms now possible, then we deserve the rut of stagnation and monotony in which the public has placed us.

We must learn to be kind to our eyes. We must learn to smooth their paths and not drag them over difficult zigzags, bumps and notches. Nor on the other hand should we bore them by leading them over the same customary, monotonous paths they have been following for years. They can be titillated by fresh new colors and contours and scientific combination of masses, just as a jaded appetite can be revived by a tangy new food.

Apparently the time has arrived for a re-consideration of buying motives as they affect product design. Perhaps we are somewhat lopsided in our reasoning. We strive and strive to make our products masterpieces of mechanical efficiency, and forget that people are still people with eyes and finger-tips and an inherent love of good proportion and symmetry. We acknowledge this factor readily on all products classed as "impulse merchandise" but are too apt to forget it when we start designing mechanical products. Our automobiles, radios, clocks, stoves, refrigerators are rarely bought on impulse; but there is nearly always some totally illogical motive that creeps in and swings the sale. In the market-place none of us is completely rational. We are still human and our minds cannot be mechanized. For this reason many a product outsells a more mechanically efficient competitor, merely because of a more subtle curve, a more pleasing line, or a fresh new contour.

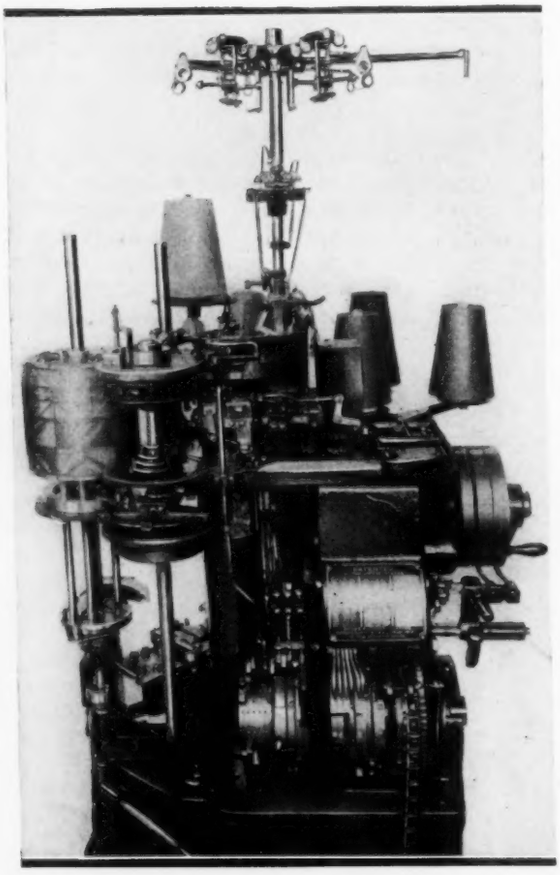
Materials Used Honestly

Amazingly beautiful things can be made from our new machine-age materials when they are used honestly by experienced designers. Sheets of colored glass, metal tubing, cellulose, compressed corkboard, phenolic laminated panels, mirrors, molded plastics, plywood, machine-made textiles, rubber blocks, aluminum, paper, concrete, metal foil—these are a few of the new structural materials placed at the disposal of industry within the past few years and which are capable of manipulation into thousands of pleasing forms and combinations. Because of their scores of variations, plastics alone have more design possibilities than industry, at its present rate, could fully capitalize in the next five years. The same holds true with concrete and alloys. Once we divorce ourselves from the belief that our new products must look like those of our grandfathers in order to be pleasing, then we are on the threshold of a new renaissance of beauty—a renaissance at last made available to the masses through the machine.

APPLYING the JACQUARD to KNITTING MACHINES

ROBERT H. LAWSON
Vice-President in Charge of Engineering
Hemphill Company

Fashion demanded full-automatic machinery for fancy hosiery—accident revealed the principle of operation—initiative and ingenuity developed the mechanical movements —another example of pioneering in design



At the left of the machine is the Jacquard cylinder which governs pattern being knitted

New styles, greater variety, better quality, and the insistent demands of fads or fashions constantly confront manufacturers of consumer goods. But in some instances the proposed or desired new style of product cannot be manufactured profitably because the machinery for its production is not available. Thus it is that fashion must sometimes wait upon the development engineer, whose efforts, in turn, are directed into definite channels by the dictates of fashion. Probably in no other industry does this occur so frequently as in the design of textile machinery, and the history of the development of the fully automatic knitting machine for fancy patterned hosiery is a striking example.

Prior to 1924, when the first commercially successful circular-knitting machines for fancy hosiery were put on the market, figures and designs were to a limited extent knitted in on the then existing automatic machines for seamless hosiery. But the products of these machines were of a distinctly inferior grade. In one method of manufacture, the knit-in design was produced by distorting the stitch. In another, two different colors were run in, one of the threads being knitted-in while the other thread was allowed to "float" on the under side. By automatically selecting when both of the two threads were to knit and when the face thread was to float with only the other yarn knitting, it was possible to make the desired design. But the product by either of these two methods was inherently weak, in the one instance because of the distorted thread, in the other, because the "floating" thread contributed nothing to the strength or wearing quality of the article. For these reasons, only expensive yarns of the highest strength could be used.

Another serious shortcoming of the fancy hosiery thus knitted was that the designs had to be limited to small figures. Large figures had to be hand embroidered or embroidered on slow and not fully automatic machines, the colored thread going in with the knitting. For these processes, highly skilled operators were required, production was slow, and the resulting product expensive.

However, the sale of even these inferior and expensive fancy stockings made it evident that if machinery were available for turning out a superior and more economical product, there would be a tremendous demand. For this reason designers of this class of machinery were given the task of developing a fully automatic machine that would knit-in any desired pattern.

As is true with so many new developments, after much wasted effort the sought for principle of operation was discovered through accident. Early in 1923, in the operation of circular and full-fashioned knitting machines, it was found that when

running two threads simultaneously, the threads somestimes criss-crossed accidentally, causing the thread that was normally on the outside to appear on the inner side, and vice versa. Yet both threads knitted in properly. With two threads of different colors, this accidental criss-crossing would result in a haphazard pattern. From this someone got the idea that by controlling the criss-crossing of the threads it would be possible to knit a desired pattern.

Reverse Plaiting Principle

In principle, it would be easy to criss-cross the threads selectively by merely bending the needle back out of line, thereby getting the same result as had been obtained by the accidental maladjustment. This method of obtaining the knitted design, now called reverse "plaiting," would evidently produce inherently superior hosiery because both threads would be knitted-in, there would be no distortion of the stitch, and the use of two yarns would make a better wearing article. Furthermore, this process would make possible the use of cheaper yarn. Thus, in one stroke, was discovered the principle for a machine to manufacture fancy hosiery, superior to the plain article, and at no greater production cost.

In all modern knitting machines, the needles, with a "sinker" between each successive needle, are mounted vertically around a circular needle-cylinder and revolve with it, the needles moving up and down in the needle cylinders and the sinkers moving back and forth horizontally. The sinkers, which are flat stampings, draw the proper amount of yarn into the stitch and cause the old stitch to cast-off or clear the needle.

In making a complete study of the problem of developing a machine that would control the criss-crossing or plaiting of the threads, three general methods were apparently available. In principle, the problem was to effect a certain definite positioning of the threads relative to the needle. This could be done by "bending" the needle, that is, giving the needle an additional movement perpendicular to its line of normal travel, which method would be a direct application of the accidentally discovered principle wherein the maladjustment of the needle caused criss-crossing of the yarn. Secondly, to obtain the desired relative positioning of yarn and needle, the thread could be given a movement, the needles continuously retaining their normal travel. A third possibility would be a combination of the two.

The Needle Cylinder

In complexity, the knitting machine ranks with the Linotype machine. The heart of the automatic knitting machine lies in the needle cylinder and its associated parts, the construction of which is shown in Fig. 1. From the notations given in the figure, one can readily understand how the sinkers are moved and the functions they perform in normal knitting.

In developing the knitting machine for plaiting, the engineers decided that the second of the above-mentioned methods would be the most logical. To give the needle a horizontal motion would introduce factors that would tend to interfere with the definitely required up and down travel of the needle for "normal" knitting. Also, it was merely a matter of reshaping the then existing sinkers and modifying their horizontal travel, to effect reversed plaiting of threads.

Elements of Pattern Control

To cause the threads to criss-cross for plaiting, it was necessary to give the sinkers an additional motion independent of that required for normal knitting. Thus, to knit a design, some means had to be devised to continuously select those sinkers that were to be given the added motion so that the sequence of plaited threads would knit the desired pattern. The first thought was to simply put projections on the outside vertical edges of the sinkers, these projections or butts being at different levels. Cams or plungers at the different levels, actuated in a certain definite order as predetermined by the pattern desired, would strike the butts at the different levels. Although mechanically this was quite satisfactory, the number of different levels of projections and the corresponding number of cams was limited by the space available. For this reason, the machine as developed on this principle could be used only for knitting relatively small and simple patterns that did not require a large number of combinations.

The second step in the development was to put the butts or projections on a piece, called a jack, separate from the sinker, as shown in Fig. 2. Funda-

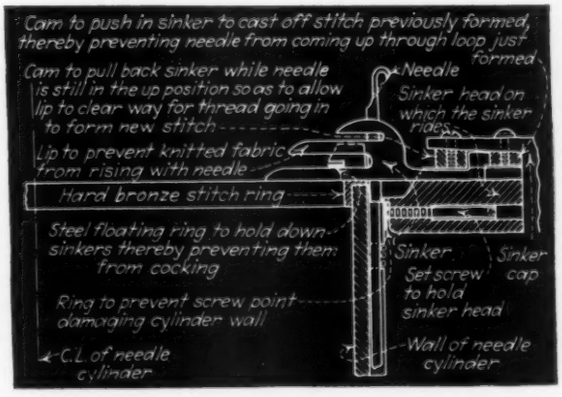

Cam to push in sinker to cast off stitch previously formed, thereby preventing needle from coming up through loop just formed
Cam to pull back sinker while needle is still in the up position so as to allow lip to clear way for thread going in to form new stitch
Needle
Sinker head on which the sinker rides
Lip to prevent knitted fabric from rising with needle
Hard bronze stitch ring
Steel floating ring to hold down sinkers thereby preventing them from cocking
Sinker
Sinker cap
Set screw to hold sinker head
Ring to prevent screw point damaging cylinder wall
Wall of needle cylinder
C.L. of needle cylinder

Fig. 1—Needle cylinder and associated parts of the automatic knitting machine which was developed for knitting fancy patterns

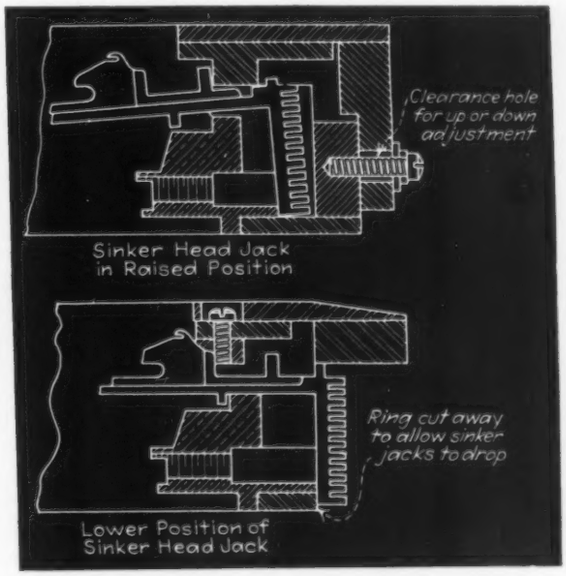

Clearance hole for up or down adjustment
Sinker Head Jack in Raised Position
Ring cut away to allow sinker jacks to drop
Lower Position of Sinker Head Jack

Fig. 2—(Right) The second step in the development was to put the butts or projections on jacks separate from the sinker

mentally, the operation was exactly the same as in the previous machine, and both designs had the inherent fault of being limited in the patterns that could be produced. Furthermore, with about 12 different plungers or cams actuating the 12 different levels of butts, it was impossible to move all of the sinkers exactly the same amount. This was because all the plungers could not possibly be made to take exactly the same position after being pushed in. Even with the greatest of precision, wear would soon cause relative changes in the plungers or cams. Another factor that could not be controlled accurately was the inertia effects.

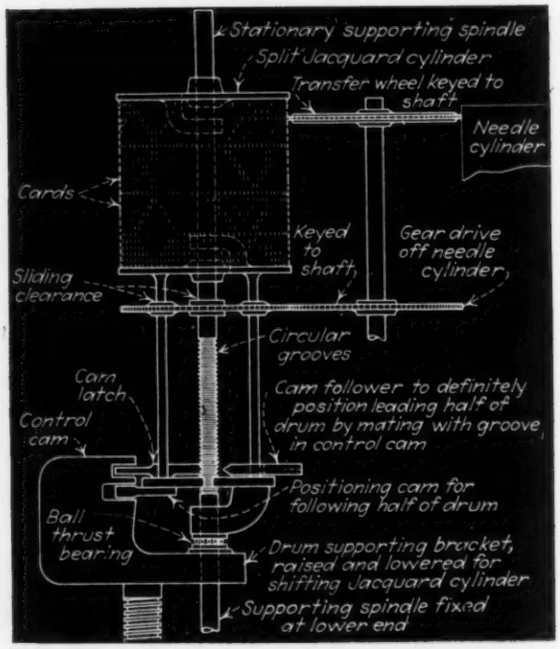

Stationary supporting spindle
Split Jacquard cylinder
Transfer wheel keyed to shaft
Needle cylinder
Cards
Keyed to shaft
Gear drive off needle cylinder
Sliding clearance
Circular grooves
Cam latch
Control cam
Cam follower to definitely position leading half of drum by mating with groove in control cam
Positioning cam for following half of drum
Ball thrust bearing
Drum supporting bracket, raised and lowered for shifting Jacquard cylinder
Supporting spindle fixed at lower end

Fig. 3—Jacquard mechanism for controlling the pattern, as finally developed for the knitting machine

Here was a perplexing problem, though the solution appears relatively simple. Reasoning that the same exact movement could be given to all of the jacks only if all of them were moved into final position by one fixed cam, the engineers decided that this would be the only logical thing to do. Thus, the movable plungers when striking the butt on the vertical edge of the jack could be made to cause the jack to move part way in. Then a second butt, located on the top horizontal edge of the jack, could be made to strike a fixed cam. With all of these butts on the upper edge located the same distance from the end of the jack bearing against the sinker, all of the sinkers would be moved into exactly the same final position.

To transform this theoretical solution into a practical operating mechanism presented another problem. The natural thought was to use a dividing cam but it proved unsatisfactory. To work successfully it was necessary that all of the jacks making contact with the plungers be thrown in sufficiently far to clear the point of the dividing cam. But the motion given to the jacks by the plungers was not controllable to such a fine degree, and it was soon found that sometimes a jack would be thrown into a position which put its top butt directly in the path of the cam point, thereby smashing the jack and possibly causing serious damage to the machine.

The problem then was to arrange the mechanism so that all of the jacks that had not been pushed in sufficiently to clear the cam point would automatically be given an additional movement that placed them out of the way of the cam. Logically, this could not be done in a simple manner by an additional horizontal movement of the jacks because the interference of the jack butts and the cam was the result of a horizontal movement. Therefore the solution of the problem had to be in the nature of adding a vertical movement to the jacks so that those which were not clear to ride on the fixed cam would be taken out of the path of the dividing cam.

In the lower view in Fig. 2 is shown the extremely simple method by which a positive separation was made between the jacks that were in a position to be acted on by the positioning cam, and all the remaining jacks. The lower end of all of the jacks rode on a supporting ring. In the circle of travel immediately after the point where the selected jacks were pushed in by the plunger, the outer portion of the supporting ring was cut away. Upon reaching this cut-out section, those jacks that had not been pushed in by the plungers dropped about $\frac{1}{16}$ in. Thus the top of the butts on the horizontal leg of the jack dropped down below the bottom plane of the fixed cam.

With this arrangement there was no possibility of smashing the jack. If the latter had not been pushed in far enough, it would simply drop down. This of course would result in a wrong stitch and thereby cause a fault in the pattern being knitted, but there would not be any damage done to the machine. Furthermore, by allowing the jacks to drop it cleared the way to locate the fixed cam to better advantage as more tolerance could be given to the position which the jacks had to take in order to ride on the profile of the fixed cam.

Jacquard Mechanism

With all of these developments, there was still a distinct drawback to this automatic machine; the size and complexity of the design was limited by the number of possible combinations on the 12 or more cams that operated the plungers or fingers for throwing the jacks. It was realized that the adoption of a Jacquard motion which would enable the selection of any jack to plait the yarn would be a difficult matter. In the ordinary Jacquard mechanism as used on looms, the elements controlled by the mechanism are relatively stationary, that is, the piece acted on by the Jacquard mechanism has no motion other than that given to it by the mechanism. On the other hand, in the circular knitting machines the parts to be actuated, namely the jacks, are rotating at about 200 r.p.m. Therefore, whatever mechanism was to be adopted would have to be such that it could be balanced at this high speed of rotation. Also, it had to be a card or the equivalent thereof, that would revolve with the whole needle cylinder and would not unbalance it.

The first step in this final development was the design of a card such as used on a Jacquard mechanism, and putting this card on a drum revolving at the same speed as the needle cylinder. The card was simply a circle of prongs extending out from the card cylinder or drum. Each prong corresponded to a certain jack mounted on an intermediate transfer wheel, there being one jack for every sinker. The jacks on the transfer wheel were free to slide radially. If

a given card-cylinder prong were omitted, the jack on the transfer wheel was not moved in radially and therefore remained in position to act upon the sinker. Thus, by omitting selected prongs on the card cylinder, the stitch at any one needle would be reverse-plaited. With only one card on the drum, the yarn would be reverse-plaited at the same needles at each revolution.

It was of course necessary to develop the design so that any number of cards could be mounted on the one drum and that contact between the jack wheel and drum could be shifted from one card to the next. This presented another problem because it would be impossible, on account of the mesh between the prongs on the card and the jacks to shift the drum axially.

Control Mechanisms

Apparently, there could be only one possible way of shifting the contact between the drum and the jack wheel to bring another card into mesh. That would be by splitting the drum longitudinally into two independent halves, each half being free to be moved axially independent of the other. Thus, while the prongs on the one-half of the split drum would be in contact with the jack wheel, the other half of the drum could be moved axially without affecting the mesh between the prongs and the jacks. After 180 deg. of rotation, that half of the drum which had been in contact with the jacks would be completely out of mesh and could then be shifted to match with the other half that had previously been shifted axially.

To convert this idea into an operating mechanism it was necessary to develop a movement that would shift the one-half of the drum an exact multiple of the vertical distance between successive cards. It was also necessary to develop a mechanism so designed that after the first half of the drum had been shifted to its new axial position, the second half would be compelled after about 180 deg. of rotation to move into exactly the same plane.

Following out this idea, the design as shown diagrammatically in Fig. 3 was developed. Each half of the drum is mounted on two vertical rods on which it is free to slide, the rods rotating with the drum. Each pair of rods is fastened into one of the halves of a split collar. A fixed bar, fastened at its lower end to the frame of the machine, serves as the shaft upon which the whole drum unit rotates. The vertical position of the leading half of the drum is at all times determined by the vertical position of the drum supporting yoke, the weight of the drum being carried by a ball-thrust bearing while a collar prevents the drum from being lifted relative to the yoke. Thus, the leading half of the drum can be raised or lowered by raising or lowering the yoke, it being arranged that such a movement takes place only when that half of the drum is not in mesh with the jacks on the transfer wheel. The vertical position of the following half of the drum is determined by a latch mounted on the split ring as indicated in the figure. This latch is in the shape of a bell crank, one end fitting into circular grooves in the central shaft or axis that carries the whole drum mechanism. The pitch distance between the grooves is exactly the same as the pitch distance between successive cards on the Jacquard cylinder. As long as this latch is meshed with grooves in the vertical central shaft, it prevents its half of the drum from moving either upward or downward.

In the operation of this Jacquard mechanism, a specially developed mechanical movement causes the yoke to rise or fall a distance equal to an exact multiple of the vertical distance between successive Jacquard strips or cards, this movement taking place while the following half of the drum is in contact with the jacks on the transfer wheel. While this movement is taking place, the bell-crank latch holds the following half of the drum in its vertical position. After the whole drum mechanism has rotated approximately 180 deg., the leading half of the drum will be in contact with the transfer wheel while the following half will be entirely out of mesh. The cam latch then makes contact with the cam mounted on the yoke, as indicated in the figure, thereby releasing the latch that fits in the grooved rings of the vertical axis. The following half of the drum is then free to move axially either up or down, and by means of two cams, is pulled into the vertical position that coincides with the position that the leading half has taken. After a rotation of approximately 45 deg., the latch and cam are out of contact, thereby permitting the latch to mesh with one of the circular grooves in the vertical axis. The two halves of the drum now coincide in their horizontal plane and the contact between the jacks and the Jacquard cylinder has been moved or transferred from

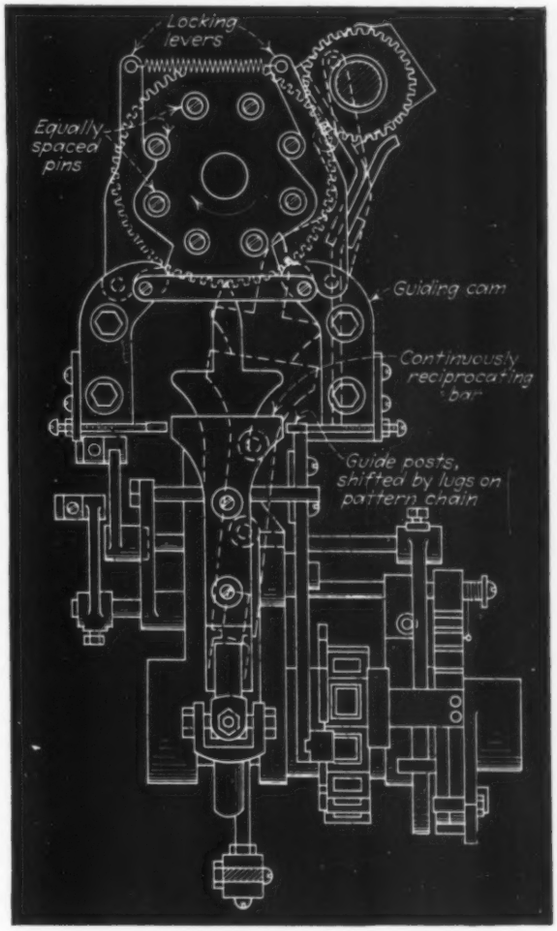


Fig. 4—A new mechanical movement to control the position of the Jacquard cylinder was invented to replace the ordinary ratchet mechanism

one card of prongs to another.

It is evident that the cam yoke must be moved with extreme accuracy so that the movement of the Jacquard cylinder will always be an exact multiple of the distance between successive cards. It was first attempted to use a ratchet drive for rotating the nut that raises and lowers the cam yoke mounted on the threaded shaft. This appeared to be an extremely simple method for accomplishing the desired result as it was merely necessary to have lugs on the pattern chain to control the ratchet which in turn caused the required rotation for elevating or lowering the cam yoke. But the required accuracy was lacking; the ratchet caused an over-travel of the ratchet wheel. Furthermore, there was no means for locking the nut in any given position to prevent movement of the yoke.

In order to overcome the difficulties presented by the ratchet device, a mechanical movement such as shown in Fig. 4 was developed, a study of which will reveal its manner of operation. The pointed operating bar is reciprocated continuously by a bell crank or eccentric. In the position shown dotted the bar point has made contact with one of the pins on the gear wheel to give a rotation as indictated by the arrow, the guide ears in passing between the guide posts having caused the bar to be thrown to the right. It will be noticed that the side of the arrowhead opposite the point of contact with the pin is bearing against the right-hand locking lever. Therefore, the continued forward motion of the bar will cause the locking lever to swivel and thereby unlock itself from the pin. This will free the wheel for rotation in the direction of the arrow. As the reciprocating bar advances further, the lug near the point of the bar will ride on the guiding cam, thereby swiveling the bar into its central position and causing the gear wheel to rotate.

For rotation in the opposite direction, it is merely required that the guide posts swivel the reciprocating bar toward the left. Furthermore, it will be evident that there will not be any rotation of the gear wheel unless the guide posts have swiveled the reciprocating bar to one side or the other. Also, the angle through which the gear wheel rotates will be always exactly the same, it being dependent solely upon the spacing of the pins in the wheel.

In this mechanical movement, the guide bars are actuated by lugs placed on the pattern chain. In this manner, the nut that controls the elevation of the cam yoke is rotated as desired thereby shifting the card-drum so that the predetermined pattern as set up by the pattern chain and Jacquard cards will be knitted.

New Data on the Holding Power of Nails

A thesis by E. Leonard Ihl and James Trealor, University of Pittsburgh, reports the results of an investigation on the holding power of ordinary, galvanized and cement coated nails, and also discusses the holding power of clinched nails.

With ordinary wire nails driven across the grain into white pine, the force required to withdraw a 10-penny nail increases almost uniformly from 45 lb. at $\frac{1}{4}$ in. penetration to 200 lb. at $1\frac{1}{2}$ in. penetration. For 16-penny nails, these figures are 97 lb. at $\frac{1}{4}$-in. penetration and 280 lb. at $1\frac{1}{2}$-in. penetration. For 20-penny nails, the figures are 65 lb. and 340 lb. Corresponding figures for wire nails in oak are given as 110 lb to 750 lb. per 10-penny nails; 175 lb. to 750 lb. for 16-penny nails; and 160 lb. to 770 lb. for 20-penny nails. Apparently, the diameter of the nail has relatively little effect on its holding power when the nail is driven into oak.

In the test on galvanized nails, probably the most outstanding characteristic is the uniform increase in holding power with the size of the nail when driven into either white pine or oak.

Cement coated nails of different diameters were tested. Results show that the greater the diameter of nail, the greater will be its holding power when driven into pine, whereas when driven into oak the increase of holding power with respect to nail diameter becomes relatively slight. Comparing the ordinary wire nail, the galvanized nail, and the cement coated nail, for 10-penny nails driven to a depth of 1 in., the force required to withdraw them is as follows: For 10-penny nails, 140 lb.; 10-penny galvanized nails, 245 lb.; 10 penny cement-coated nails, 275 lb.

Tests on clinched nails revealed that about the same force is required to pull a nail that has been clinched $\frac{1}{2}$ in. as one that has been clinched an inch or more. It was also found that there was no difference in average holding power between a nail clinched along the grain or across the grain. The thickness of the board in which the nail is clinched has no great effect on the holding power of the nail.

In summarizing the results of their tests, the authors have drawn the following general conclusions:

1. The relative holding power of an ordinary wire nail driven into oak and yellow pine is about 3.4 to 1.
2. The relative holding power of a galvanized nail driven into oak and yellow pine is about 2.5 to 1.
3. The relative holding power of a cement-coated nail driven into oak and yellow pine is about 1.5 to 1.
4. In oak a galvanized nail will hold about $1\frac{1}{4}$ times the load of an ordinary wire nail.
5. In pine a galvanized nail will hold about 1.6 times the load of an ordinary wire nail.
6. A cement-coated nail, when driven into pine, is about 14 per cent stronger than a galvanized nail, and about 42 per cent stronger than an ordinary wire nail of the same diameter.
7. A galvanized nail has, when driven into pine, 25 per cent greater holding power than the wire nail. In oak the percentage drops to about 19.
8. When a wire nail is driven into oak and clinched $\frac{1}{2}$ in. or more, the holding power is increased by about 37 per cent.
9. When a wire nail is driven into pine and clinched $\frac{1}{2}$ in. or more, the holding power is increased by about 120 per cent.
10. In oak, a wire nail has roughly 15 per cent less holding power when driven parallel to the grain. In pine, this figure is about 33 per cent.
11. The holding power of a nail does not vary directly with the surface in contact with the wood.
12. As a general conclusion, the relative holding power of wire nails, galvanized nails, and cement coated nails is about 1–1.25–1.35. These figures are based on average values.

Product Development and Research

"It will not pay any private concern to carry on scientific and industrial research. . . . Any manufacturer who entertains ambiguous notions concerning product development will be painfully surprised." The author is a graduate of the Russian Imperial Naval Academy, received his Master of Science degree from Case School of Applied Science, invented numerous devices, and for seven years has served in his present capacity in charge of research and development.

LEV. A. TROFIMOV
Development Engineer
Electric Controller & Manufacturing Company

Since its inception, the course of engineering activity has changed twice—once when the germ of mass production was discovered in the form of manufacturing interchangeable parts, and second, when industry adopted research—and as a consequence of this, produced the development or product engineer. It seems that the appearance of the development engineer in industry is a phenomenon similar to the appearance of the very first engineer. He is a natural product of industry.

Inventing versus Developing

In attempting to define a development or product engineer, we cannot fail to come to the conclusion that the function of a development engineer is inventing. If someone does not like the word "inventing" we may say that the function is that of applying physical principles or information, usually obtained by research, to an industrial product.

The development engineer has specialized not only in applying the physical principle, but also principles of production, sales, service and maintenance; all of which should be and are incorporated in any successful industrial product. For this reason the orthodox conception of "inventing" does not convey correctly the idea of development engineering. In bygone days, inventors were regarded as impractical people; they had ideas but it required practical engineers to make an industrial product out of the idea. A better definition perhaps is this: A development engineer is one who specializes in solving industrial, technical problems. His activities and responsibilities range from the conception of an idea to the final form of the industrial product.

Of course there is nothing new about such an activity. There have always been men in industry who invented things, developed, manufactured, and put them on the market. However, before the advent of research, the number of people of this type and ability who happened to be present among the industrial workers was apparently sufficient to meet the needs of industry for such work. A product once invented and introduced on the market enjoyed a comparatively long life. Now the situation is entirely different. The average life of any product is extremely short. Competition encourages change. Change forces the adoption of research, and in turn, research accelerates the tendency for further and more rapid changing, so that now, as C. F. Kettering says, "There is nothing as constant as change."

The Industrial Need

The industrial need for men who can readily conceive improved ideas and develop them to the state of a commercial product, is tremendous in this day. The fortuitous and indiscriminate way of meeting this need, as it has been done in industry, is entirely inadequate. Symptoms of comprehension of the situation and of an attempt to meet it, are found in the conscious effort of selection.

Industry went through its personnel with a fine comb, separating all those who had even a slight tendency toward development engineering, and putting them in the research and development laboratories and telling them to "do their best." This is how and where the development engineer was born.

Research and Profits

But knowledge alone is no longer the key to industrial progress. It is, in addition, an ability to invent, to convert the findings of research into a commercial product. It is an ability to solve industrial technical problems in all their complexity, quickly and economically. This constitutes at present the master key to a glorious future of industrial development.

We can be assured that the development engineer, first of an entirely new series of engineers, has come to industry to stay. There are several other kinds of the same series of engineers now in the making, such as research, production, sales, service and maintenance engineers. The fundamental difference between the conventional engineers and the new series may be expressed in the words, —informational versus functional.

The product development engineer has been crystallized somewhat more definitely than the others, which gives rise to two important questions:

1. If there is a need in industry

for development engineers, how shall that need be met?

2. If there is such a thing as a development engineer in industry, there must be some kind of development engineering. In fact, if colleges are to recognize the situation and meet the need, they must have the pattern from industry. Therefore, what is development engineering?

Before the development engineer is recognized by colleges and the first one is made by them, there is an actual situation in industry which must receive prompt attention.

The value of research to industry in general is fully recognized and huge sums of money are spent yearly on it. At the same time it is erroneously but faithfully believed that research is yielding profit directly. In other words, it is assumed that the security of dividends is directly proportional to the amount of research carried on by the concern.

If this were strictly true, the smaller concerns which do not maintain research departments would have been doomed to obscurity. Nevertheless there are a good many businesses that cannot afford to carry on research as large ones do, but which still pay steady dividends and show no signs of weakening. Instead of research departments they support an expedient with the ambiguous name of "Development laboratories." This expedient is fully responsible for their stability and good prospects.

Will Research be Socialized?

The reasons for such an anomaly are several. First of all, research does not yield any profits directly. Nor can research findings be retained as exclusive property, but become a common possession after being once applied to the manufactured product. This first application is, of course, protected by patents, but there is no guarantee that this protection will enjoy a long enough life to pay for the expenses of research. As a rule, the first application is never the best, and saddest is the fact that it reveals the secret. After that he who finds the best application reaps the most profits.

The above considerations, together with the fact that research is extremely expensive, lead to a reasonable conclusion that in the future the strictly research activities will be semi-socialized as are the co-operative researches of today, or fully socialized such as the work of the U. S. Bureau of Standards. It will not pay any private concern, no matter how large, to carry on scientific and industrial research. The center of gravity of commercial attention will be chiefly located in the development. Any manufacturer who believes in the omnipotence of research and invests heavily in it, meanwhile entertaining ambiguous notions concerning product development, will be painfully surprised in the near future.

Although development departments and laboratories are established facts they are, in my opinion, either managed in an inadequate way, not managed at all, or even mis-managed. Perhaps there are a few exceptions to this, but the situation cannot be otherwise, chiefly because of newness, and also because of undue intoxication by research.

If it were possible to manage a development department efficiently, as we understand efficiency, as applied for instance, to a production department, there would be another "revolution" in industry. However, the question is whether or not such management is at all possible. The situation is entirely different from that in production departments. In production departments we deal primarily with physical operations whereas in development we have to deal with mental actions. If efficiency in the development is possible what are the principles of it?

It seems to me that the immediate future of industry must rest totally on the proper answers to these questions. Speaking generally, at the present time we are at the beginning of a new industrial era which can be described as the era of demanding an efficient and sufficient use of mental energy.

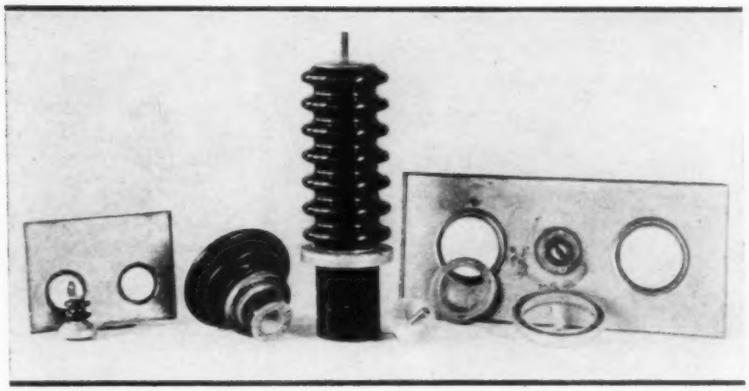
"Mist Plating"

To the list of finishing processes available to the engineer and designer may soon be added a "mist" or "dry" process of metal plating without electrodes, developed by Dr. John Strong, Norman Bridge Laboratory of Physics, California Institute of Technology. The process may be said to be original in that it takes place in a vacuum jar or chamber, requires a high heat and may be applied both to metal surfaces and to any relatively non-aqueous materials such as paper, dry wood, cloth, glass and leather.

In laboratory practice a sliver of the plating metal is placed inside a small tungsten wire coil suspended between two metal posts or standards. Electric current is sent through the coil, heating it and the metal within. At high temperatures a fine metallic mist begins to rise within the vacuum chamber, covering with unusual uniformity everything within it. Successful mist plating has been accomplished with platinum, gold, silver, tin, aluminum, iridium and copper. It is believed that nearly any metal whose "mist heat" is less than that of tungsten will serve equally well. Electricity is used only as a heating medium and plays no other part in mist plating, which has little in common with the electrolytic method.

According to Dr. Strong, "Nearly any material in a relatively high degree of dehydration may be metal plated by the vacuum-heat methods. The system employs neither anode nor cathode, and while it has not yet been handed to the commercial field, I see no reason why it should not have considerable application there. We have used it for metallizing mirrors. Heretofore plating has been pretty much confined to putting a metal surface on other metals, but the mist system opens wide the doors to numerous other materials.

"Probably the thinnest plating yet done has been accomplished by the vacuum method. We have plated glass with gold of a thickness of only 1/50th Mu, which is approximately 0.00001 in. This is 1/25 the thickness of the finest oil film visible to the human eye. . . The manufacturing of relatively perfect vacuums in chambers of considerable size is not an obstacle to the utilization of this process. In industrial practice, a metallic chamber, perhaps with observation ports, would probably succeed the bell jar of the experimental series. Very small amounts of metal are needed to plate surfaces. It semes to me that the mist process has opened the way to the commercial application of metals to materials formerly ignored because of inherent difficulties in plating, and lack of a controllable method. We spent two years of research and experiment in developing the process."



Success in soldering metal to porcelain is the result of pioneering in a comparatively unworked field

SOLDERED CERAMICS

J. E. MATEER

General Insulator Engineer, Material and Process Engineering Department
Westinghouse Electric & Manufacturing Company

In the design of electrical apparatus, many problems arise which require joining metal to porcelain or glass in a manner that will permit continuous operation at temperatures ranging from —40 to +150 deg. F. Frequently these parts are of relatively large size and weight; the porcelain part itself may weigh 50 lb. or more.

Such assemblies may be required to operate underground completely submerged in water for indefinite and unpredeterminable periods. For this purpose gaskets have been employed between machined metal faces and ground porcelain faces, but they have not been entirely satisfactory, especially when the joints must retain hot insulating oil. The brittleness of vitreous ceramic materials places awkward and expensive limitations on such devices. The size of metal sections must be sufficient to prevent even minute distortion when tightening gaskets.

In order to avoid these limitations and to obtain more permanent joints, the Westinghouse Electric & Manufacturing Company has developed a method of attaching porcelain and glass to metal by soldering. The process, which has been patented, consists in producing a platinized area on glass or on glazed porcelain surfaces by suitable treatment in a furnace. The platinized surface may be tinned and soldered to metal parts with a commercial solder, held within close temperature limits, by operators specially trained for such work. The joints are relatively strong and as permanent under the same conditions as soldered joints between metal parts. The solder adheres so closely to the porcelain that the glaze, together with part of the porcelain, gives way when the joint is ruptured.

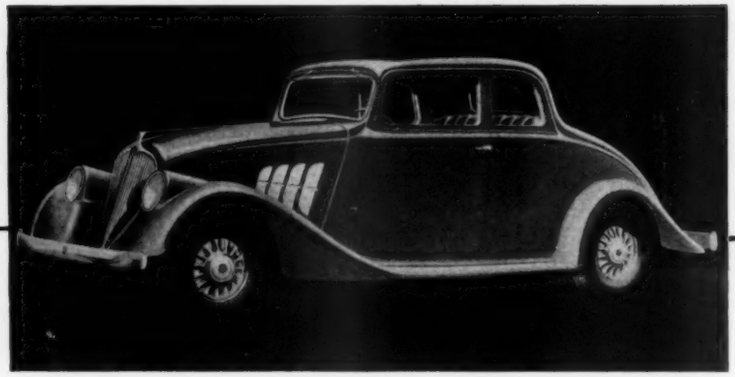
An important point which vitally affects the design of the various parts is the large difference in coefficient of expansion of metal and of porcelain or glass, the metal coefficient being five to six times greater than that of porcelain and three times greater than that of glass. There is, therefore, mechanical stress on the porcelain or glass, if it is on the inside of the metal parts, in cooling down from the soldering temperature to room temperature and to the still lower temperatures encountered under outdoor service conditions. To prevent these stresses from becoming dangerous, the metal parts must be designed as light as possible and the ceramic parts with the maximum ruggedness. When this is done, it is possible to subject the complete assemblies to rapidly changing temperatures between 150 and —40 deg. F. covering the complete range of seasonal temperature changes without failure of porcelain, or any impairment of the joint.

Typical of the applications of soldered ceramics are the parts for oil-insulated capacitors shown in the accompanying illustration. Such capacitors must be sealed permanently. When porcelain terminal bushings are used, it has been difficult and expensive to seal them because of the necessity for grinding the porcelain and machining the metal flanges to receive suitable gaskets. By soldering a hollow threaded metal stud to the end of the porcelain bushing and a pressed thin metal flange to the outside, an inexpensive unit has been produced. This unit is placed in a suitable orifice in the tank top after drawing the capacitor lead through the hollow stud. The bushing flange is then attached to the tank by soldering. The lead from the condenser is knotted and soldered to a cup-shaped recess in the end of the hollow stud. The outside of this threaded stud forms a binding post for attaching external conductors without risk of breaking the seal. On the average size of bushing used for this purpose, the saving per bushing has been from $1.00 to $1.50.

It is often required to provide a window in the side walls of a tank or treating chamber where the use of gaskets is objectionable. Such a window can be produced by soldering heat-resisting glass to a thin metal frame which in turn can be soldered in any desired location. Likewise, in the mounting of tubular glass sight gages, the usual gaskets may be replaced by thin flexible ferrules of copper soldered to the glass at each end. The ferrules are then soldered to the main part of the gage forming a permanent leak-proof construction.

In conclusion it may be well to cite that soldered ceramics have proved successful in potheads, oil-sealing bushings, vacuum-tight bushings—especially for mercury arc rectifiers—soldered drop-outs on lightning arresters, glass cans with metal ends, and sight gage glasses for transformer and circuit breaker tanks.

The Willys line will appear with the most radical stream-



lining ever designed into a production motor car

Trends in Automobile Design

As Evidenced by Passenger Cars in the Low Priced Bracket

Probably for the first time in history automobile design is showing a divided trend. Goaded by our higher gasoline taxes and lower buyer incomes, the designers of one group are going in for smaller, lighter cars. Designers of the other group are still actuated by the philosophy of bigger cars for less money. Representative of the one, Plymouth comes out with a wheelbase of 107 in. as against 112 in. in 1932, but it is only fair to say that it is now a Six instead of a Four. Representative of the other, Chevrolet will still be a Six, but it will have a wheelbase of 110 in. instead of 109.

One automobile designer states that the Essex Terraplane started the trend toward smaller, lighter cars. Though the idea has not caught on as well as it might in the American market, smaller cars are making great sales records in export. Even so, it is predicted that Essex will appear in 1933 with a standard 56-in. tread instead of 51-in. tread. It is freely predicted also that advertisements for 1933 will claim 30 miles per gallon for each of several American cars. Here too, designers must have their eyes on export trade because 30 miles per gallon means 36 miles to the Imperial gallon.

According to one well-known commentator on automotive design, who wishes his name withheld, the new cars will probably not do better than 25 miles per gallon in the hands of the casual driver. Even so, the motor public can look forward to worthwhile economies brought about by better balanced design, increased use of alloy steels, better workmanship—rather than by any radical changes in engine design. The conventional passenger car in the low-price bracket will have a weight-power ratio of approximately 50 lb. per horsepower. The new Essex Eight, however, will probably have a weight-power ratio of 30 lb. per horsepower.

Nothing Known About Ford

Of the new Ford line, nothing whatever can be said definitely. Gossip says that there will be a six-cylinder Ford; gossip says that there will be two Eights instead. Take your choice. Continental will make its first bow on the market with a Four on a 101½-in. wheelbase, a Six on a 107-in. wheelbase, and a larger Six details of which have not been released. Although nothing definite can be learned even about the smaller Six, it is known that the Four will be a car of rather conventional design built for the lowest price market but with several unusual characteristics, including an improved spring mounting and considerable weight reduction through the use of the lighter alloys.

As a contrast, the new Willys line will challenge the same market with a Four and a Six streamlined more radically than any production car yet to appear. All models will use floating power under Chrysler license. Headlamps sunk in the front fenders will be used for the first time in cars selling under $2,000. As shown in the illustation, the pressed steel wheels will have a spoked effect.

During the most successful days of Dodge history, this line of cars was designed to sell at just above the lowest price group of cars. Dodge designers in making possible a renaissance of this price policy provide a smaller automobile with floating power, free-wheeling and all the "fixings."

The Rockne, since it appeared comparatively late in 1932, will continue with several body refinements as yet undisclosed.

The 1933 models will give the purchaser the impression that his old car is completely outdated and outmoded. Probably the most radical innovation will be seen in the Fisher "No-Draft" ventilation system on the Chevrolet. This feature, which will be incorporated on all General Motors closed cars, is a simplified application of the adjustable suction louvre idea whereby the outside air supply may be effectively controlled at the will of the driver or by the passenger sitting next each window. The "louvre" is in effect an adjustable windshield wing controlled by an irreversible

worm gear regulator holding it in any set position.

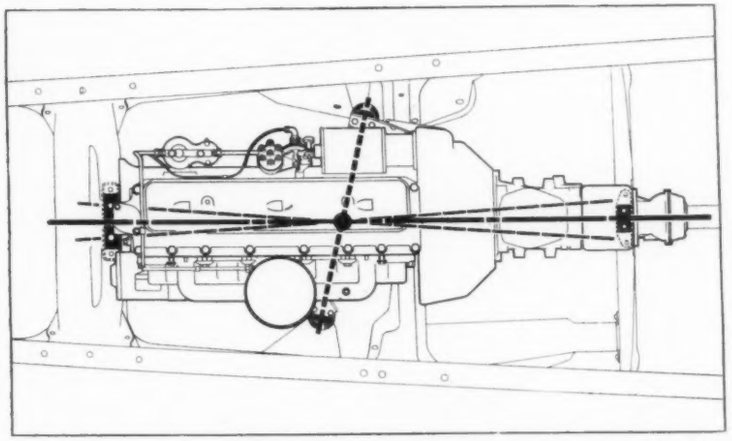
This swinging part of the window forms a front section. The rear section, in front doors, slides up and down in the regular way and when raised forms a tight joint excluding drafts and permitting locking. In rear windows, the rear section is stationary. Air enters at the front. It is drawn out at the back of this adjustable wing so that a vortex is formed near that one window whose sectional area is controlled by the angle to which the wing is opened. With small openings, this effect is localized in one or more parts of the car.

Pontiac will appear in one straight eight chassis at "an exceedingly low price." It is said that it will feature a five-point engine mount, details of which are not available. Its designers are providing fenders ribbed for strength and appearance. In fact, fenders will be found to have received a great share of attention on all 1933 cars.

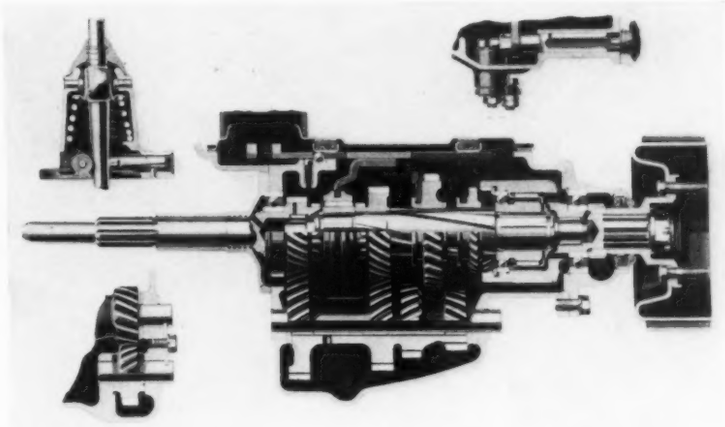
Trends in Detail Design

In general it may be said of the 1933 list of low-priced automobiles that front axle design will be conventional with the one known exception of the Plymouth tubular construction. The cooling efficiency of radiators, most of which will be of the V-type, will be increased on almost every car. Chevrolet, for example, will have an increased cooling capacity of 18 per cent. Wheels will be smaller—most of them 17 in.—but the designers seem to be showing natural conservatism about adopting "air wheels" or "doughnut tires" as standard equipment. According to recent reports, De Soto will be the only low-priced car to carry doughnut tires as standard equipment—and then only on "deluxe" models. Tires will be 7 in. in cross-section on 15-in. wheels. Though wire wheels will continue their vogue, at least two cars will use pressed steel with spoke embossings.

As suggested above, the new motors will be conventional except for details and refinements, such as inserted Stellite valve seats. Fuel pumps will be continued as standard equipment. Both air cleaners and oil filters will also be standard. One car in particular will follow the high-price practice of placing the hand brake on the left of the driver. The starter button on the Willys will be placed on the dash just above the accelerator pedal. Rubber will be used as insulators or dampeners more freely than ever. Several cars will even mount mufflers and tail pipes on rubber. Practically all brakes will be of the Centrifuse type. Except for Chevrolet and Pontiacs which will continue General Motors practice by using tinned cast-iron pistons, aluminum alloy pistons will continue as standard. Coincidental starting will be featured on Chevrolet and De Soto.



Mounted on a sub-frame, the Chevrolet engine will have considerable freedom of movement, both oscillating and in the horizontal plane. Practically all of the weight is carried on two lateral supports, as differentiated from "floating-power" practice



In the Plymouth transmission helical constant-mesh gears provide silent second gear operation. The shift lever is mounted on a frame cross member and is in contact with the assembly only when shifting gears

Silent Second Standard

In almost all cars the designers will provide transmissions with silent seconds, and some cars will have all forward speeds silent. Although not strictly in the low-priced group, De Soto will even have a silent helical reverse gear, necessitating a helical splined shaft. Spiral bevel gears will continue to be standard for rear axles; mufflers will be of the baffle type. Although the effective area of clutches will be increased in certain cars the design will be conventional. While free-wheeling will continue as a feature on most of the low-priced cars, neither the Willys nor the Continental will feature it. Double-drop "X" frames will also be regarded as standard design in 1933.

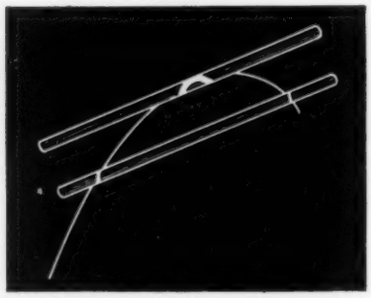
Although the changes on 1933 passenger cars will not be regarded by the engineer as basic, it may be said with confidence that there have never been so many changes in so many cars at one time. It is evident that the manufacturers mean business. One trend may be away from the bigger cars of yesteryear, but it will be evident that the designers have provided sound design as their contribution to economic recovery.

COMMUNICATION and COMMENT

Simple Method for Constructing Tangents

HERBERT F. BARAFFI

There are many instances in engineering where data are obtained in terms of some independent variable. If the equations can be set up we may investigate some properties by differentiating. But many times it is impossible or impracticable to set up any equations, in which case we must differentiate graphically by finding the tangents to the curve. Thus if we plot the results of a tensile test on rubber as stress versus strain, the modulus of elasticity is the slope of the curve. Still another case deals with finding the forces acting on the connecting rods of a radial motor. Where it is impossible to set up simple equations, the path of the rod is plotted. This is then differentiated twice, hence giving its acceleration.



By rolling the glass rod on the curve, the spot where the image breaks away from the edge of the glass indicates the point of tangency, the position of the rod being the slope of the tangent

In all the above cases tangents must be drawn to the curves at various points—at best a slow and inaccurate job. Some engineers use the "mirror differentiator" which gives fairly accurate results. But one is seldom available when needed.

For a simple and accurate method of getting tangents to a curve, all that is needed is a slender glass rod such as a stirring rod. Lay the rod across the curve as shown in the sketch and roll or slide it towards the outside; that is, the rod is actually a moving secant, and of course a tangent is the limiting position of a secant through a fixed point and a moving one as the length of the internal segment of the secant approaches zero. As the rod is rolled, the two points approach each other, the curve being greatly magnified. Where the image just breaks away from the edge of the glass, mark the point. Then, without moving the rod, draw a line along it as though it were a straight edge. This line is parallel to the tangent at the point. The angle can then be measured and its tangent found.

This little differentiator does more than that, however. Whereas the mirror differentiator will give the slope at any point, it is not feasible to work it conversely. But the little glass rod will do this easily. Suppose it is required to find a point on the curve where the slope is to have a given value. Lay off this slope anywhere in the area, place a straight edge along this line and put the rod along it. Then roll the rod toward the curve, and the required point will be found as explained above.

Calculating Sag in Suspended Chains

WILLIAM W. JOHNSON

Quite often in the design of machinery it becomes necessary to determine the sag in a flexible chain or cable when the length and span are known. The curve of suspension, assuming a cable or chain of uniform density, is the common catenary. This will be the curve whether or not the line joining the points of support is horizontal. The accompanying Figs. 1 and 2 illustrate the two possible conditions.

A complete discussion of the mechanical properties of the catenary can be found in most textbooks on mechanics. But for computing the sag, a table of hyperbolic functions is necessary. The method presented here reduces the mathematical computations to a minimum.

In the simpler of the two types of construction, the points of support of the chain are at the same level, as shown in Fig. 1. To illustrate the computations by an example, it will be assumed that the chain is 100 in. long and is suspended from two points 50 in. apart. It is required to find the sag. Referring to the figure we have:

$$s = \frac{100}{2} = 50$$

$$x = \frac{h}{2} = \frac{50}{2} = 25$$

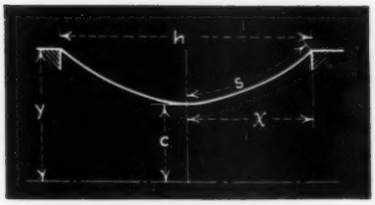


Fig. 1—The sag in the cable can be calculated easily by the method given in the text

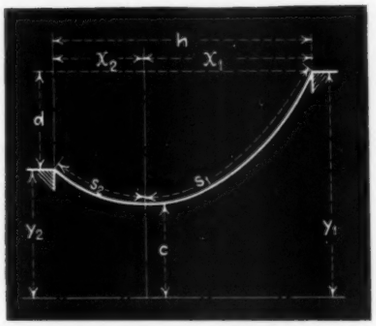


Fig. 2—A suspended chain or cable takes the catenary curve even when the supports are not at the same level

From the properties and equations of the catenary it can be shown that:

$$\frac{s}{x} = \frac{\sinh\,(x/c)}{(x/c)} = \frac{50}{25} = 2. \quad (1)$$

Let

$$u = \frac{x}{c}, \quad \text{or} \quad c = \frac{x}{u}$$

Substituting in Equation (1),

$$\frac{\sinh u}{u} = 2.$$

Assuming different values for u, and referring to tables, we find

$$u = 2.17733.$$

Hence

$$c = \frac{x}{u} = \frac{25}{2.17733} = 11.482.$$

$$y = c \cdot \cosh \frac{x}{c} = c \cdot \cosh u$$

Substituting,

$$y = 51.30 \text{ ft.} \quad (2)$$

$$\text{Sag} = y - c = 51.30 - 11.48 = 39.82 \text{ in.}$$

A more difficult problem is one in which it is required to find the lowest point of the chain when the points of support are not on the same horizontal line. As an example, assume that a chain 100 in. long is supported at two points 80 in. apart horizontally and 30 in. vertically, as shown in Fig. 2. From the notations in the figure, we have:

$$l = s_1 + s_2 = 100 \text{ in.},$$
$$h = 80 \text{ in.}$$
$$d = 30 \text{ in.}$$

Then

$$2c \cdot \sinh\left(\frac{h}{2c}\right) = \sqrt{l^2 - d^2} \quad (3)$$

$$= \sqrt{(l+d)\,(l-d)}$$

$$= 10\sqrt{91}$$

$$2c \cdot \sinh\left(\frac{h}{2c}\right) = 95.394 \quad (4)$$

Putting

$$u = \frac{h}{2c}, \quad \text{then} \quad c = \frac{h}{2u}$$

Equation (4) may be written:

$$\frac{h}{u} \sinh u = 95.3939,$$

$$\frac{\sinh u}{u} = \frac{95.3939}{h}$$

$$= \frac{95.3939}{80}$$

$$\frac{\sinh u}{u} = 1.1924.$$

By means of tables of hyperbolic functions such as found in Campbell's "Numerical Tables," we get:

$$u = 1.0455,$$

Then

$$c = \frac{h}{2u} = \frac{80}{2 \times 1.0455}$$

$$c = 38.259 \text{ in.}$$

$$x_1 + x_2 = h = 80 \text{ in.}$$

$$x_1 - x_2 = c \cdot \log_e\left(\frac{l+d}{l-d}\right)$$

$$= 38.259 \log_e\left(\frac{130}{70}\right)$$

$$x_1 - x_2 = 38.259 \times 0.6191$$

$$x_1 - x_2 = 23.686 \text{ in.}$$

Therefore

$$x_1 = 51.843 \text{ in.}$$

Then

$$y_1 = c \cosh \frac{x_1}{c}$$

$$= 38.259 \cosh 1.35505$$

$$y_1 = 79.10 \text{ in.}$$

$$\text{Sag} = y_1 - (d + c) = 79.10 - (30 + 38.26)$$

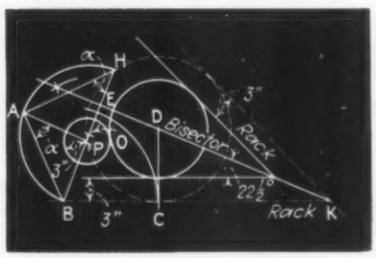
$$= 79.10 - 68.26$$

$$\text{Sag} = 10.84 \text{ in.}$$

Three More Constructions

As mentioned when the problem was presented in the November number, there are at least two geometrical constructions to locate the center of a gear tangent to two intersecting racks and meshing with a pinion of known diameter located between the racks. One such construction was given in the December number. Two more are given here, making at least three possible solutions. The following solution was submitted by John G. Real and H. C. Zimmermann, independently.

The solid lines represent the pitch line of the rack, while the pinion is shown by the circle having the center P. To obtain a circle tangent to the pitch line of the racks and tangent to the circle P, the dash lines are drawn parallel to the rack and 3 in. from them. The angle between the racks is bisected and from the point P a perpendicular is dropped on this bisector and extended to point H, making EP equal to EH. Extending this line in the opposite direction, it cuts the line KC at B. Bisecting the line BH, a semicircle is drawn with O as the center and through P another perpendicular is erected which will cut the semicircle at A. Making BC equal to BA, and erecting a perpendicular CD, locates D, the center of the re-

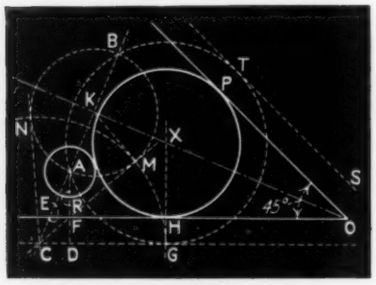


The proof of this construction is based on the theorem that the tangent is the mean proportion between the whole secant and its external segment

quired circle having radius DC.

By geometry, AB is a mean proportional between BH and BP, by similar triangles. If from any point without a circle a tangent and a secant are drawn, the tangent will be a mean proportional between the whole secant and the external segment. Therefore, BC being equal to BA, the point C will be the point of tangency between the line BK and the circle passing through points C, P and H.

A somewhat similar solution was submitted by H. G. Taylor, as shown in the accompanying figure. In this construction, the line $CAKB$ is perpendicular to the bisector OK and the lines CN and CM are drawn parallel



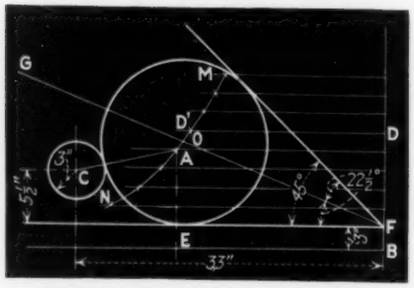
The radical axis *CB* passes through the points of intersection of the two circles, and tangents from any point in the radical axis to the two circles are equal

to the circle as shown. Making CG equal to CM, and erecting the perpendicular GHX, the center of the desired circle is obtained.

Proof of this construction is based on the theorem that the radical axis of two intersecting circles passes through their points of intersection, and tangents drawn from any point on the radical axis to the two circles are equal.

In addition to the above geometrical constructions, D. J. Reynolds gives a method wherein he plots points equidistant from the straight lines and the pinion circle.

A solution is secured by the intersection of two loci of the center of the large gear. The first locus is determined because the gear center must be everywhere equidistant from the two racks in order that the gear will mesh with them. This means that the center of the gear lies on the line FG which bisects the 45 deg. angle. The second locus is determined because the gear must mesh with the lower rack and the pinion. This means that the gear center is equidistant from C and the line BE which is 3 in. below the rack pitch line. From B an arc is struck to D and then a line DD' parallel to BE is drawn through D. With the same radius BD an arc with C as the center is struck which intersects with the parallel through D and D'. When sufficient points are plotted, we may draw the locus MN whose intersection at O locates the gear center.



Although this is not purely a geometric construction, it illustrates another method of obtaining the required center

Concerning Quality of Drawings

C. D. HAEDRICH

Chief Draftsman Artillery Division, Frankford Arsenal

I have read with much interest Alfred C. Layzell's article "Clarity in Dimensioning," which appeared on page 421 of the October, 1932, number of *Product Engineering*. I do not agree with some of the points brought out in that article. A draftsman would not make a "trick drawing," as Mr. Layzell calls it, intentionally. Every good draftsman makes his drawing as he thinks it should be made and dimensions it as he would like to have it dimensioned if he were going to make the piece. Should a draftsman continue making "trick drawings," in spite of instructions to the contrary, he should be discharged, or perhaps put in the shop where he soon would have impressed upon him the proper method of dimensioning drawings.

As to the other items wherein I disagree with Mr. Layzell, slots should always be dimensioned from the extreme ends and not from the radius center to radius center. The position of the slot should be located from its center line.

As to dimensioning holes, if, for example, there are eight holes shown on a drawing, six of which are alike and two of which are of another diameter, the notation on the drawing should read "Six – 0.25 drill" and "Two – 0.281 drill" with arrows pointing to each hole.

Length of studs should be taken from the extreme ends unless special ends are required, and should not be expressed as the length of full diameter required, that is, not including the radius of the ends.

With reference to designating all angles from one direction, this is an approved method but cannot always be worked out.

With reference to the eighth item in Mr. Layzell's article, I do not believe that an operator or machinist could be so dumb as to think that he has to make his dimension 0.495 in. when the dimension is specified as ½ in. — 0.005. But this brings up another thought. In dimensioning drawings all outside diameters of rods, shafts or bars should be specified as the maximum size with a minus tolerance. All thicknesses of pieces should be specified the same way. For holes, the minimum size with a plus tolerance should be given.

With reference to giving dimensions in feet and inches, all dimensions on machine drawings should be given in inches. Dimensions in feet and inches should only be used on civil engineering drawings.

In no case should a drawing be dimensioned in the metric system and the English system on the same sheet.

It is bad practice to repeat dimensions on drawings, and therefore I can see no reason why the depth of a recess should be given when the diameter is the proper dimension to be shown.

With reference to the last item in the above-mentioned article, I can see no reason why the material to be used should be shown with greater prominence than any other note or dimension on a drawing. As long as the name of the material is legible and the machinist sees it, that is all that is necessary. Then if "tool steel" is the material called for and

the machinist goes and gets a "brick" to make the piece, that is no fault of the draftsman's.

The greatest fault that I find with drawings is that some firms do not have a standard place for the various notations required.

Erratum

To the Editor:

In the December number, page 512, you give a chart of comparison of hardness scales and tensile strength, the chart showing the relationship between Rockwell *C* and Brinell hardness and also that between Rockwell *B* and Brinell hardness. I wish to call attention to the fact that the chart has been erroneously marked "Rockwell *D*" for the lower scale of abscissas, whereas Rockwell *B* was intended.

This is particularly unfortunate inasmuch as there is a Rockwell *D* scale which applies when the penetrator is a sphero-conical diamond Brale and the major load applied is 100 kg. All of the Rockwell scales, together with the standard Brinell scale, are shown on sheet WM-16.1 of the Rockwell Hardness Tester direction book.

C. H. WILSON
Wilson Mechanical Instrument Company

Poisson's Ratio versus Density

In the November issue of "Machine Design Clearing House," a bulletin that is distributed among college professors teaching machine design, Professor W. J. Dana states:

"In looking over the values of Poisson's Ratio I was struck with their similarity to the weight per cubic inch of the same material. For example:

Material	Wt. per cu.in.	Poisson's Ratio
Cast Iron	0.260	0.270
Wrought Iron	0.277	0.278
Steel	0.283	0.303
Copper	0.318	0.333
Brass	0.300	0.333
Lead	0.411	0.430

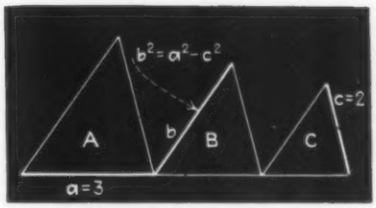
"There is probably some relation between the density of the material and its change in volume per unit volume under a given stress. I have never seen this mentioned before, and am wondering whether others might have noticed this similarity and can give a possible explanation for it."

A Problem in Triangles

FRANCIS W. SHAW

It was required to make three similar triangular plates as shown in the accompanying illustration, such that the weight of *A* should be equal to the weight of *B* and *C* combined. On account of the manner in which these plates were later to be positioned, the sides *a*, *b* and *c* had to be so proportioned as to form the sides of a right-angle triangle, such that $b^2=a^2-c^2$. Furthermore, it was essential that *a* should be 3 in. and *c*, 2 in.

The problem was solved after considerable effort, but the solution indicated that only one particular shape of triangle could be used. Apparently, this can be proven by geometry, but in order that other readers may exercise their minds on what proved to be an extremely interesting problem, the solution will be withheld for a subsequent issue.



How can the remaining sides and angles be determined? The area *A* is to be equal to the sum of areas *B* and *C*

DEFLECTIONS

PRESIDENT-ELECT ELECTS MONEL

It is reported that President-Elect Franklin D. Roosevelt is having a a new tub, lined with Monel metal, installed in his winter home in Warm Springs, Ga., where he can take warm sulphur water baths under the direction of his physician. Electric heating units are built in the tub to regulate the temperature of the water.

GREASE REMOVAL

To remove greasy or dirty finger marks from drawings, *Engineering News-Record* recommends the use of powdered magnesia. Spread powdered magnesia on both sides of the stain; place drawing between two sheets of blotting paper; press blotting paper with hot iron. When powder is shaken off, stain will be gone.

VACUUM CONTROL FOR TRIANGLES

When a draftsman has considerable fine cross-section work to do, it is frequently difficult to handle triangles on a drawing board. One draftsman, according to *Railway Mechanical Engineer*, purchased an automobile anti-glare shield in a five-and-ten-cent store and removed the rubber suction cups. Placing the cups on the triangles afforded an easy way to handle them, as well as a rest for his finger tips.

POUND FOR POUND

According to *Power*, one pound of magnesium makes a $2\frac{1}{2}$-in. cube or a $\frac{1}{2}$-in. square bar 64 in. long. One pound of steel makes a $1\frac{1}{2}$-in. cube or a $\frac{1}{2}$-in. square bar 14 in. long. One pound of ingot magnesium costs 30 cents; one pound of ingot steel costs 2 cents. By the pound magnesium bars cost fifteen times as much as steel; by the cubic inch, only three and one-half times as much.

DIE-PRESSED MALLEABLE

Presses of 100 to 750 tons capacity are coming into general use for pressing malleable castings to size and shape. Using specially-designed dies, these presses form and straighten the castings, often holding them within tolerances of 0.005 and 0.010 in. According to *Steel*, this pressing frequently takes the place of machining and thus eliminates large items of cost.

RUBBER VS. WATER-HAMMER

Many are the ways in which rubber is used as a noise deadener, but here is a new one to us. A $\frac{3}{4}$-in. hydraulic pipe developed a noisy water-hammer due to fluctuating pressure. An engineer of the B. F. Goodrich Co., substituted a piece of $\frac{3}{4}$-in. hose for a section of the pipe. The trouble ended.

Developments in Equipment Design at the Power Show

For the first time in its decade of history, the mechanical engineering exhibits at the Tenth National Exhibition of Power and Mechanical Engineering, New York, N. Y., Dec. 5-10, outnumbered power exhibits. Although this year's show was not so large as in former years, and clearly indicated the desire of most manufacturers to restrict expenses, it was none the less a valuable source of information for engineers and designers.

Power exhibits reflected the trend toward improved operation in the many showings of meters and automatic controls for almost every purpose in power generation and industrial processes. With exceptions such as a medium-size stoker, a cupola blower delivering a constant weight of air per lb. of fuel and iron, and a medium-size air-conditioner, no large equipment was exhibited. But what was lacking in exhibits of this kind was more than compensated for by many displays of cross-sectional photographs and drawings of large equipment and plants.

As an example, one manufacturer displayed cross-sectional drawings of seven different types of boiler plants. These included plants of both the indoor and outdoor types, the latter being the very latest advance in plant design. These drawings were in several colors to clearly indicate the flow of fuel, air, water, steam and the gases of combustion. The automatic combustion-control equipment installed to regulate these plants was also included on the drawings, so as to give a complete picture of the plant's operation.

From the viewpoint, however, of the purely mechanical engineer and designer, the motor and speed-reducer exhibits were more informative. One outstanding trend was shown in the number of exhibits of geared-head motors. In one booth, units for parallel, right-angle and vertical mounting were shown, to meet any space or machine drive requirement. Where the speed-reducer is the larger of the two, the motor is supported from it.

Pump exhibits comprised a number of types including centrifugal, rotary, gear, plunger and vacuum heating pumps. The number of self-priming pumps demonstrated indicated a tendency toward this type. In some of these the self-priming feature is made part of the pump's design, where in others a priming device is provided to maintain the pump primed at all times.

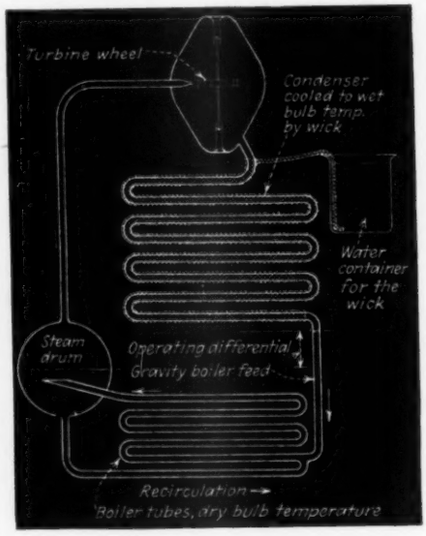


Diagram of vacuum vapor power plant shown in operation at Power Show

Among the new metals shown was a new alloy of copper and nickel for condenser tubes, and another of beryllium-copper. Copper sheet produced by the new electroplating process was shown in several thicknesses including one no thicker than paper.

From the number of exhibits featuring flat leather and rubber belting, it would seem that the manufacturers are embarking on an active campaign against the inroads of the V-belt. Exemplifying another instance of competition were the exhibits of two manufacturers of joints and fittings for copper tubing. One featured a joint wherein the end of the tube is smeared with a paste consisting of solder and flux. The tube is then inserted into the slightly tapering opening of the fitting and the flame of a blowtorch applied. When a red band on the outside of the fitting turns black by reason of the heat, it serves as a signal to indicate that the solder has melted and that the joint is complete. The other exhibitor pushes his tubing into place and allows melted solder to distribute itself inside the joint by capillary action.

Of great general interest also was a lettering device whereby letters from $\frac{3}{16}$ in. to over $\frac{1}{2}$ in. in height can be made rapidly from a templet. Of this, more will be said in a later issue.

Strangely enough, however, the "hit of the show" was a little exhibition device approximately 3 ft. in height made of glass tubing—the "Vacuum Vapor Power Plant," as shown diagrammatically in the accompanying illustration. This consists of a boiler in which steam (or vapor, if you will) is generated by the heat of the surrounding atmosphere, a nozzle through which this steam jets upon the buckets of a turbine wheel mounted on jeweled bearings, and a condenser cooled by a wetted wick. The condensate returns to the boiler by gravity, as in mercury boiler operation. In an ordinary atmosphere the turbine wheel will spin indefinitely so long as the wick is kept moist. In principle this little power plant is comparable to Claude's deep sea thermal power plant, upon the development of which vast sums of money have been expended.

Engineering Fundamentals Stressed at A.S.M.E. Annual Meeting

Engineers have always been faced with the necessity of getting results. They have been forced more often than not to make temporary use of assumptions, theories, formulas and test methods of doubtful validity. Frequently they have been saved

from grief by liberal factors of safety. All too often these assumptions have later been accepted as engineering "laws." But the engineers who presented papers at the annual meeting of the American Society of Mechanical Engineers, New York, N. Y., Dec. 5-9, displayed a healthy skepticism regarding such matters. Paper after paper re-analyzed the old "laws" and the old assumptions.

For example, in the most heated session of the meeting, William F. Parish, and Leon Cammen announced that lubricating oil reclaimed from automotive engine drainings provides a more efficient lubricant than new oil. According to their joint detailed report, ten-year tests tend to show that "re-refined" oil reduces crankcase temperature, gives increased mileage per quart of oil, and increases engine speed, by acting as a more perfect lubricant. A member of a university mechanical engineering department asserted in rebuttal that the tests in the report did not present sufficient data to permit of conclusions. He seemed to feel that the only conclusion that could be drawn was so amazing as to be decidedly doubtful. An oil company representative termed the tests "ridiculous," saying that he was astounded that such a paper "should be submitted."

Specialists in mathematics, mechanics, metallurgy and strength of materials contributed much in two sessions on working stress. One of these was devoted entirely to metals at high temperatures, and the closely related problem of "creep." Apparently a whole new technology of creep is being developed. It is common knowledge that creep tests extended no more than 1,000 hr. have been applied to designs intended to be used for 100,000 hr. P. G. McVetty brought out in his paper that there is a steadily increasing creep rate for a certain period, then a practically constant rate for a long period, after which the rate of elongation begins to increase once more. Ernest L. Robinson reported similar findings.

Though fans have been tested, too little attention has been given to such matters as pulsations in air flows and the influence of bends in inlet ducts. These fundamentals received timely attention.

In the hydraulic session much attention was given to re-examination of the still tentative theories of turbine design. Working partly by theory and partly by rule of thumb, hydraulic engineers have made magnificent achievements. Further progress must involve a better knowledge of the fundamentals.

With this meeting, A. A. Potter, dean of engineering, Purdue University, assumed the presidency of the A.S.M.E. New officers inducted with him are Messrs. J. D. Cunningham, H. V. Coes and C. F. Hirshfeld as vice-presidents,

A.S.A. Standard Rotating Air Cylinders and Adapters

Developed to obtain interchangeability of different makes of air cylinders on the spindles of machine tools without changing the adapters or draw rods, a new American Standard on Rotating Air Cylinders and Adapters has been approved by the American Standards Association.

Three sizes of standard adapters cover the range of standard air cylinders from 3 to 18 in. inclusive. Adapter "A" fits the 3-in. and 4½-in. cylinders; adapter "B" fits the 6-in. and 8-in. cylinders; and adapter "C" fits all sizes of cylinders from the 10-in. to 18-in. inclusive. A fourth size, adapter "D," is also included to accommodate the 20-in. air cylinder or other power-operated devices having a draw rod pull of 26,000 to 40,000 lb. The length of stroke of the standard cylinders, the position of the piston rod at the end of the stroke, and the diameter of the tapped hole in the piston rod have also been standardized.

MEETINGS

American Engineering Council—Annual meeting, Washington Hotel, Washington, D. C., Jan. 15. L. W. Wallace, secretary, 744 Jackson Place, Washington, D. C.

American Institute of Electrical Engineers — Winter convention, New York, N. Y., Jan. 23-27. H. H. Henline, secretary, 33 W. 39th St., New York, N. Y.

American Society of Heating & Ventilating Engineers—29th annual meeting, Cincinnati, Ohio, Jan. 23-25.

Society of Automotive Engineers—Annual meeting, Book-Cadillac Hotel, Detroit, Mich., Jan. 23-26. Annual dinner, Hotel Pennsylvania, New York, N. Y., Jan. 12. John A. C. Warner, secretary, 29 W. 39th St., New York, N. Y.

Gray Iron Institute — General meeting, Congress Hotel, Chicago, Ill., Jan. 26.

EXHIBITIONS

National Automobile Show — Grand Central Palace, New York, N. Y., Jan. 7-14, and Chicago, Ill., Jan. 28-Feb. 4.

National Alliance of Art and Industry—Exhibition of "New Materials, New Products and New Uses," 65 E. 56th St., New York, N. Y., Jan. 16-Feb. 15.

National Association of Engine and Boat Manufacturers—Annual Power Boat Show, Grand Central Palace, New York, N. Y., Jan. 20-28.

American Management Association — Third Annual Packaging, Packing and Shipping Exposition, Conference and Clinic, Hotel Pennsylvania, New York, Mar. 7-10.

Product Design Lecture

On Dec. 15, George F. Nordenholt, associate editor of *Product Engineering*, delivered his talk on "The Commercial Aspects of Engineering Design" to the A.S.M.E. student branch and the industrial engineers at Lehigh University. This lecture, which has been delivered at several technical schools and engineering society meetings, emphasizes those phases of product design other than stress calculations.

Exhibition of New Materials, Products and Uses

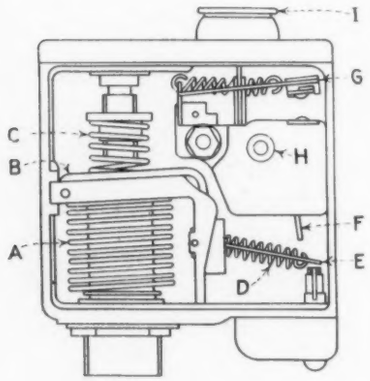
National Alliance of Art & Industry Inc., announces an exhibition of "New Materials, New Products and New Uses" to be held in the galleries of the Art Center Bldg., 65 E. 56th St., New York, N. Y., Jan. 16-Feb. 15.

The range of exhibits will be wide: electrical equipment; molded products; developments in the motor and airplane industries; novel household equipment; new uses for glass, for metal alloys, for rubber and for many synthetic products; new developments in lighting, heating and ventilating equipment as well as devices which simplify the mechanics of daily life. The test for eligibility of exhibits will be their design quality; mere technical excellence or novelty will not in themselves be enough to insure inclusion in the exhibition. Further details may be obtained from the Exhibition Secretary of the Alliance.

NEW MATERIALS and PARTS

Cutler-Hammer Bulletin 10016 Pressure Switch

In an exceptionally compact design. Employs same inclosure and operating parts as C-H refrigerator control. Silver contacts are double-break; overload is standard C-H thermal type; Sylphon bellows, which takes place of customary diaphragm, has total movement of only about $\frac{1}{32}$ in. All parts rustproof. In operation, bellows *A* pushes arm *B* against action of loading spring *C* carrying spring *D* over center. Snap action provided; design eliminates all roller and cam mechanisms. Flipper *E* entirely free of any heavy operating levers reducing working forces to minimum. Flipper pushes bakelite bar *F* against switch *G* to open it at



high pressure, and releases it to close switch at low pressure. Thermal overload *H* operates upon same switch mechanism and releases reset button *I* showing red band to afford visual indication of existence of overload condition. Changes in pressure within system cannot close switch after overload has occurred until button has been pushed to reset switch, whereupon automatic operation is restored. Adjustment of opening pressure and differential can be made from without inclosure upon removing seal which effectively prevents unauthorized and accidental readjustment. Bakelite inclosure houses entire mechanism. Available in single and double pole types. Wiring compartment for inclosed wiring furnished on request. Cutler-Hammer, Inc., 12th & St. Paul Ave., Milwaukee, Wis.

Garlock 660 Sheet Packing

For gasoline, oil and water is produced by new process which combines granulated cork with tough paper fibre bound together by means of liquid-proof compound. Claimed to be soft enough to seal flanges or joints which may be imperfectly machined or in poor condition, and tough enough to permit use in paper thicknesses on installations requiring very thin gaskets; will not shrink, crack, curl or become brittle in stock. Available in all standard thicknesses from 0.010 to $\frac{1}{2}$ in. In thicknesses under $\frac{1}{8}$ in., available in rolls 36 in. wide or in sheets. In $\frac{1}{8}$ in. and greater available in sheets 36 in. square. Gaskets cut from this material are styled Garlock 661. Garlock Packing Co., Palmyra, N. Y.

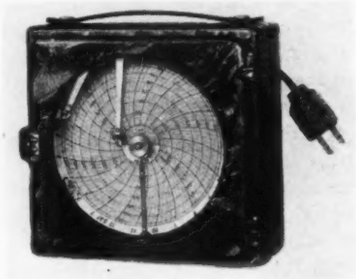
I.R.C. Power Wire Wound Resistors

In a complete line from 3 watt to 15 watt. Features listed by manufacturers include: band of metal molded at ends of windings with resistance wire brought through molded end to assure positive contact; lugs or wire leads molded in; special insulated coating to withstand high humidity without sacrificing ability to withstand high temperatures; insulating coat a good conductor of heat; sizes unusually compact. The 3-watt resistor manufactured up to 5,000 ohms is about same size at $\frac{1}{2}$-watt

standard I.R.C. metallized resistor; 5-watt resistor manufactured up to 15,000 ohms; 10-watt resistor up to 30,000 ohms; 15-watt up to 50,000 ohms. Available with lug or fuse-clip terminals. International Resistance Co., 2006 Chestnut St., Philadelphia, Pa.

"Tag" Miniature Recording Thermometers

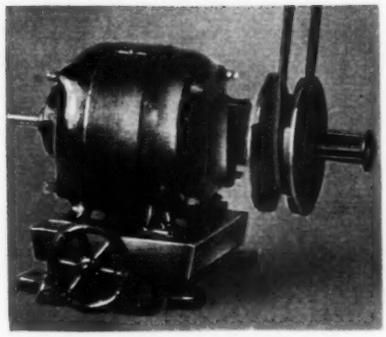
Developed in two forms: a single-pen recording thermometer for charting temperature only, and a temperature and time-operation recorder as illustrated. Latter writes continuous record of temperatures as well as



running and idling time periods of motor. Square case and door made of aluminum castings. Special non-breakable transparent front. Dimensions: $5\frac{3}{4}$ in. high; $5\frac{3}{4}$ in. wide; $4\frac{1}{4}$ in. deep. C. J. Tagliabue Mfg. Co., Park and Nostrand Aves., Brooklyn, N. Y.

"Acme" Variable Speed Units

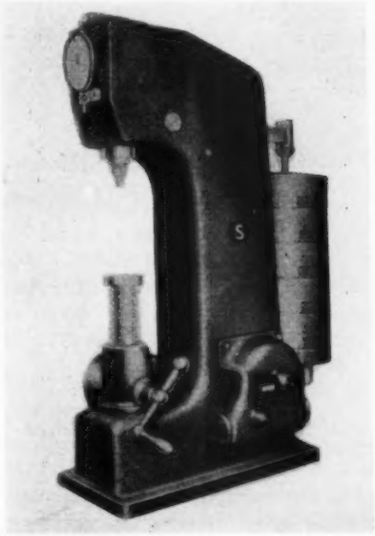
Available with standard V-belt drive, roller chain drive, silent chain drive or gear drive. Drive pulley of V-belt unit shown in illustration composed of two intermeshing side castings keyed in spiral keyways cut left and right hand against load. Claimed that the harder the pull the harder the belt will force side castings into V-cut spiral keyways. Spring which carries no load has push and pull action on side castings and reacts on them through spiral keyways. Inter-



meshing design of side castings allows unit to use any make V-belt of proper size. This unit, which can be furnished in horsepowers from ½ to 40, has only one adjustment, a handwheel on motor base. Roller chain and silent chain models are of similar design. Ratios adjustable from 2½:1 to 1:1. N. J. Oak, 22 Hawthorne St., Lynn, Mass.

"Superior" Hardness Testing Machine

Model US-300, motor driven, with pushbutton control, is designed to apply the load by the dead weight system rather than by hydraulic loading. Thus possible to incorporate depth measuring device which in conjunction with movable scale permits hardness tests to be made quickly and read direct without the use of Brinell microscope. Screw table for holding specimens elevated and lowered by a crank. Available for Brinell tests from 250 to 3,000 kilograms. Maximum vertical opening for specimens, 11½ in.; throat depth from center of specimen table to housing, 4¾ in. Can be secured also in hand-operated type or as floor machine. Steel City Testing Laboratory, 8843 Livernois Ave., Detroit, Mich.



Crouse-Hinds Type FLC and FLFC "Condulets"

Single or double-pole explosion-proof circuit breakers for use as required by the National Electrical Code for service entrance or branch circuit protection. Fuses not required ahead of these circuit breakers. External handle operates handle of circuit breaker within inclosure, and may be operated "on" and "off" like any tumbler switch. In case of overload or short circuit, thermal element trips circuit breaker automatically

and handle takes position between "off" and "on" position. Threaded covers made of an aluminum alloy. Operating shafts, screws, etc., of stainless steel. Cadmium-galvanized is the standard finish. Ratings: 15 amp., 125 d.c. or a.c., single pole, to 50 amp., 250 d.c. or a.c., double pole.

Type FLFC is a motor starter rather than a circuit breaker. Similar in construction to Type FLC except that housing is somewhat larger and mechanism is triple pole instead of single or double pole. Should not be confused with FLC because it is not approved for protection against short circuit and requires such protection ahead of it on the line. Applicable to 2- or 3-phase, 3-wire a.c. motors ranging from 3 hp., 115 volt, to 7½ hp., 575 volt. Crouse-Hinds Co., Syracuse, N. Y.

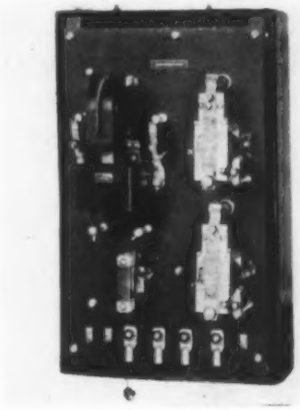
Fafnir 34DD-2, 36DD and 33-4 Ball Bearings

Type 34DD-2 said to be smallest double-seal ball bearing ever offered in this design. Especially recommended for aircraft control systems; protected against exposure. Takes hardened aircraft bolt. Full ball complement for maximum static capacity. Comes pre-packed with lubricant. Dimensions shown on accompanying drawing. Type 36DD has same specifications as 34DD-2 but is

slightly larger in size. Type 33-4 is miniature design claimed to be smallest, lightest complete ball bearing ever made. Especially adaptable to instruments and other very light, delicate bearing applications. Has no seal. All three types are precision ball bearings. The Fafnir Bearing Co., New Britain, Conn.

G.E. Mill-Type Starters

For constant speed d.c. motors. These utilize newly developed accelerating contactors designed both to act as a relay to provide time delay and to short out the starting resistor by means of a contact finger. New accelerating contactor replaces two



conventonal devices, namely, accelerating relay and contactor.

Each starter mounts the following devices: one line contactor, equipped with interlock for under-voltage protection (when used with momentary contact start button); one to three magnetic time accelerating contactors; one thermal overload relay; one starting resistor. Manufacturers

claim unusual mechanical and electrical simplicity. Accelerating contactors equipped with silver-faced tips to eliminate oxidation difficulties. Available in sizes from 1 hp. to 75 hp. General Electric Co., Schenectady, N. Y.

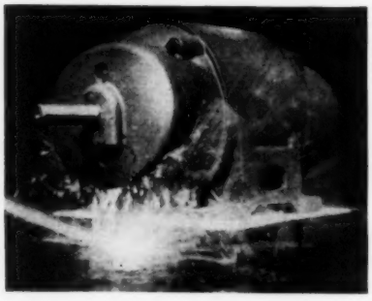
Norma Hoffman "CD" Ball Bearings

Available in light, medium and heavy metric series in range from 10 mm. to 100 mm. bore. These duplex double angular contact units, de-

signed to meet need for bearings adapted not alone for radial loads but also for high thrust loads in either direction. Width no greater than standard single-row ball bearing. Outer ring made in two parts; inner and outer raceways ground to special curvature suitable for safely carrying heavier end thrust. Should be used only where thrust load exceeds radial load. Duplex outer ring should be clamped tight in housing. One-piece ball retainer of extruded bronze rides, or is carried, upon ground flanges of inner ring. Norma Hoffman Bearings Corporation, Stamford, Conn.

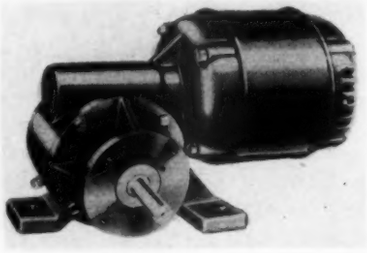
Louis Allis "Splash-Proof" Motor

Said to be first to prevent entrance of water under pressure and splashed from any angle, yet adequately ventilated and built in same dimensions as standard open motors. Double baffle in elliptical-shaped air passage in each endbell provides protection. Permits free passage of ventilating air, yet traps and drains water splashed into air openings. Another feature is shaft guard which breaks force of stream directed along shaft extension. Accompanying unretouched photograph shows one of eight practical tests in which motor, while operating at 1,800 r.p.m., was subjected to direct streams of water splashed from various angles. The Louis Allis Co., Milwaukee, Wis.



Janette "SW-2" Motorized Speed Reducer

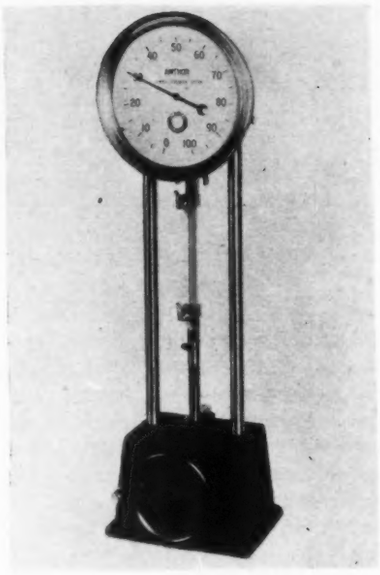
Consists of a ball-bearing Janette motor built integrally with a worm gear reduction unit. End frame of motor forms part of gear housing; worm is keyed to motor shaft extension. Slow-speed shaft fitted with tapered roller bearings. Unit shown in illustration fitted with "foot-and-single-flange" mounting with flange on right-hand side. Also available with flange on left, or both sides; or



with foot mounting only. Flange-type units furnished either with or without mounting feet. Twelve ratios, ranging from 90:1 to 8:1 have been adopted as standard; intermediate ratios and ratios up to 120:1 obtainable. Motors available from $\frac{1}{6}$ to 1 hp. in standard speeds of 1,725 and 1,140 r.p.m. Janette Mfg. Co., 556-558 W. Monroe St., Chicago, Ill.

Amthor Tensile Testing Machine

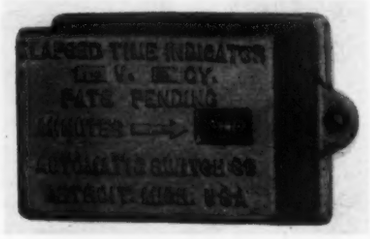
Has dynamometer spring movement specially designed for tensile breaking strength testing of wide variety of materials, so constructed that proper test sensitivity and elimination of friction are assured by free-floating movement throughout. When specimen breaks, pointer remains at tensile breaking strength. Dial $8\frac{1}{2}$ in. in diameter, graduated directly in fractions of either pounds or kilograms, and hand calibrated for accuracy. Jaws and jaw travel on Type 270 illustrated can be had in full conformity with standard test methods



for any material such as wire, sheet, rubber, etc. Amthor Testing Instrument Co., Inc., 309 Johnson St., Brooklyn, N. Y.

"SM" Elapsed Time Indicator

Designed primarily for indicating time a feeder circuit is out, but also adapted for use as lost time indicator on production machines where, in connection with ordinary Veeder counter indicating number of pieces produced, it gives correct data for time study. On electric welding sets and similar apparatus, it indicates directly amount of non-productive time. Indicator driven by self-starting synchronous motor. Available in 110

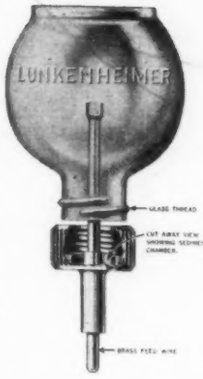


and 220 volts at commercial frequencies. Dimensions: length $5\frac{3}{8}$ in.; height $2\frac{3}{4}$ in.; width $3\frac{1}{4}$ in. Automatic Switch Co., 6420 East Lafayette Ave., Detroit, Mich.

Lunkenheimer Bottle Oiler

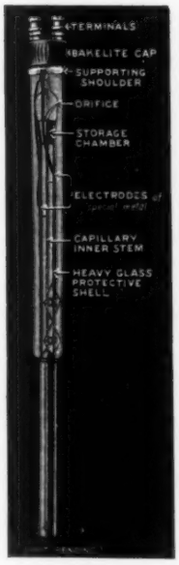
Consists of three major parts: glass bottle with threaded neck; bronze base with integral sleeve-type

shank; brass feed wire. Resilient cork washer seals joint between bottle and base. Claimed entirely automatic in operation, feeding only when shaft is in motion. Two principles involved in feeding oil down feed wire: "thermal breathing," a periodic expansion and contraction of air within bottle due to changes in temperature; "capillary creep," aided by the agitation of feed wire when shaft is in motion. The Lunkenheimer Co., Cincinnati, Ohio.



H-B Double Diamond Thermo-Regulator

Of the adjustable mercury type for accurately controlling constant temperature of ovens, heating baths, refrigerants, rooms, incubators, etc. Claimed to be sensitive to 1/10 deg. throughout entire range —0 deg. to +300 deg. F. Features listed by manufacturer: mercury purified through special process; capillary and reservoir filled with dry hydrogen to dampen spark at contact point; electrodes, or contacts, of special alloy metal, expressly designed to contact on top of mercury; terminals for connecting control circuit, eliminate danger of breaking of old style, delicate "pig-tail" leads to electrodes; outer glass shell, completely inclosing delicate parts, adds rigidity to completed instrument. For operation in conjunction with relays designed to operate within 12 milliamperes at 110 volt, 60 cycle, through protecting condenser and resistors. Relays can be furnished in three types of inclosing cases. Size of thermal regulator proper 10½ in. over-all. Available in types to maintain temperature ranges of 0 to +300 deg. F., and —10 deg. to +60 deg. F. Hiergesell Bros., 2522 N. Broad St., Philadelphia, Pa.



Cromaloy Flux

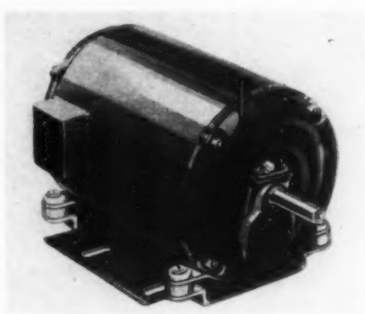
Has been developed especially for use in welding chromium-containing alloys such as stainless steel or rustless iron. Claimed to be sufficiently fireproof to protect molten metal and hot metal adjacent to weld from oxidation, and at same time to dissolve infusible oxides such as chromium oxide. The Linde Air Products Co., 205 E. 42nd St., New York, N. Y.

Nelson Section Liner

Designed to facilitate cross-hatching. Being made in one piece of laminated phenolic resonoid, liner takes little room on drafting board. In operation insert liner between T-square and triangle; after first line is drawn move triangle to opposite notch of liner and draw second line; hold triangle in position, move liner to position for next line, move triangle to opposite notch and draw line. H. Anthony Nelson, 727 N. 7th St., De Kalt, Ill.

Howell "Built-In" Capacitor Motors

Available in three types: vertical motor with machined register mounting; vertical motor with flange mounting; rubber-mounted horizontal motor as illustrated. Capacitor built inside motor frame giving each unit appearance of conventional motor. These Type CI motors furnished either with waste packed sleeve or double sealed ball bearings. Splash-proof frame. No radio interference. Available in five fractional horsepowers from ⅛ to ½, 110 volts, single phase, 60 cycle, a.c., at 1,735 r.p.m. full load speed. Separate stators and rotors furnished for built-in equipment. Howell Electric Motors Co., Howell, Mich.



Century Split Phase Motors

In new ratings from 1/60 to ½ hp. End brackets gray cast iron, designed to protect motors from falling objects, dust or dripping water. Frames rolled steel construction. Bearings machined from phosphor bronze castings. Wool yarn system of lubrication claimed to assure one year's continuous 24-hr.-per-day operation without re-oiling. Century Electric Co., St. Louis, Mo.

Waldron All-Steel Silent Gears

In patented construction said to combine strength and long life of steel with added advantages of silent service and self-lubrication. Built up of many thin pieces of sheet steel, coated with graphite and subjected to heavy pressure. Appearance that of ground steel gear of ordinary construction. Claimed in service to take on smooth glass-like polish on teeth, with mating gear taking on similar polish. Gears may be run in mesh with any gear commonly used as mating gear for silent pinions. Makers prepared to furnish gears cut to nearly all specifications or will furnish gear blanks which cut and machine easily. John Waldron Corp., New Brunswick, N. J.—Smith & Serrell, general sales agents, Globe Indemnity Bldg., Newark, N. J.

NEW BOOKS and PUBLICATIONS

"Applied X-Rays"

George L. Clark, Ph.D. 470 pages, 6x9 in. Published by McGraw-Hill Book Co., Inc., 330 West 42d St., New York, N. Y. Price $5.

This second edition adds the results of progress made in six years to the data previously published. Among the advances reported are X-ray tubes that operate successfully at millions of volts, additional uses in medical science and, of special interest to readers of *Product Engineering*, the diffraction analysis of solid materials. Since the use of the X-ray in the study of metals is growing, no engineer can afford to neglect the subject.

"Horizons"

Norman Bel Geddes. 293 pages, $7\frac{3}{4}$x$10\frac{1}{4}$ in. Clothboard covers. Illustrated. Published by Little, Brown & Co., 34 Beacon St., Boston, Mass. Price $4.75.

The author takes up the ship, the motor car, the railway car and locomotive, the airplane, the theater, the factory, the home and other commonplaces of today. And, as might be expected of one of the pioneers in "product" or "industrial styling," he shows by text and illustration how he would redesign them for the machine age of the future. Though many an engineer will not follow him to his conclusions, the product engineer can at least read and see where the ideas of one industrial designer may very well lead.

Research Bulletins

Stanford University Press, Stanford University, Calif. Vol. 1, No. 1, of University Series on Engineering is entitled "Some Experiments on Oil Films in Complete Cylindrical Bearings" with introduction and summary by Guido H. Marx, professor of Machine Design. Subjects included: "Bearing Lubrication, Influence of Surface Velocity on Mean Film Thickness," by B. M. Green; "An Investigation of the Mean Thickness of Oil Films in Bearings," by E. O. Bennett and W. L. Rifenberick; "Oil-Film Thickness in Bearings," by R. H. Hartman and W. K. Franklin; "An Investigation of Journal Positions in a Bearing," by J. Dentraygues; "Oil-Film Pressures and Journal Displacements in Complete Cylindrical Bearings," by J. B. Balcomb and R. MacKamey. 110 pages. 101 figures. Postpaid, paper, $1.00; cloth, $1.50.

U. S. Department of Commerce, Bureau of Standards, Washington, D. C. Research Paper No. 442, "Effect of Antimony on the Mechanical Properties of a Bearing Bronze (Cu 80 : Sn 10 : Pb 10)," by C. E. Eggenschwiler, Bureau of Standards, is a reprint from *Bureau of Standards Journal of Research*, Vol. 8, May, 1932. For sale by the Superintendent of Documents, Washington, D. C. Price 5 cents.

Engineering Experiment Station, University of Illinois, Urbana, Ill. Bulletin No. 246, "Investigation of Warm-Air Furnaces and Heating Systems, Part V," by Arthur C. Willard, Alonzo P. Kratz and Seichi Konzo is published under a cooperative agreement between the National Warm-Air Heating Association and the University of Illinois.

American Society for Testing Materials, 1315 Spruce St., Philadelphia, Pa. "A.S.T.M. Tentative Standards 1932" contains all of the 226 tentative standards of the American Society for Testing Materials. 1236 pages. Price, cloth bound, $8.00; heavy paper bound, $7.00. "Symposium on Steel Castings" presents the ten extensive technical papers comprising the symposium sponsored jointly by the American Foundrymen's Association and the A.S.T.M. 254 pages. Heavy paper binding. Price $1.00 each.

Chains — Morse Chain Co., Ithaca, N. Y. Bulletin No. 51, a catalog of Morse roller chains.

Cog-Belt Drive—The Dayton Rubber Mfg. Co., Dayton, Ohio. "Catalog No. 105 Condensed" entitled "Dayton Cog-Belt Drives."

Electric Switches—The Electric Controller & Mfg. Co., Cleveland, Ohio. Specification Sheet S-10 on the EC&M Type NX master switches.

Engineering Books — McGraw-Hill Book Co., Inc., 330 W. 42nd St., New York, N. Y. 1933 catalog, including publications of Whittlesey House.

Hose — The DeVilbiss Co., Toledo, Ohio. Specification sheets covering air and fluid hose.

Laminated Synthetics — Continental-Diamond Fibre Co., Newark. 40-page catalog, "Dilecto, a Laminated Synthetic Material."

Mechanical Packing — Felt Products Mfg. Co., 1508 Carroll Ave., Chicago, Ill. "A Practical Handbook of Mechanical Packing for Industrial Uses."

Motors—General Electric Co., Schenectady, N. Y. GEA-1191A, superseding GEA-1191, "Synchronous Motors."

Motors—Howell Electric Motors Co., Howell, Mich. Six-page folder, "Howell 'Red Band' fractional-horsepower built-in capacitor motors."

Motors — The Lincoln Electric Co., Cleveland, Ohio. 4-page bulletin on Lincoln "Linc-Weld" Type D Motor.

Motors — Sterling Electric Motors Inc., Telegraph Road at Atlantic Blvd., Los Angeles, Calif. Bulletin No. 125, "The Sterling System of Direct Power Application."

Nickel Cast Iron—The International Nickel Co., Inc., 67 Wall St., New York, N. Y. The first of a series of data sheets, "Guide to the Selection of Engineering Specifications for Grey Cast Iron."

Oilers—The Lunkenheimer Co., Cincinnati, Ohio. Booklet No. 532, "Bottle Oilers."

Paint — The New Jersey Zinc Sales Co., 160 Front St., New York, N. Y. Booklet, "Using Paint as Light."

Phosphor Bronze — The Riverside Metal Co., Riverside, N. J. 32-page catalog, "Riverside Phosphor Bronze."

Pressed Steel — Worcester Pressed Steel Co., Worcester, Mass. "Fine Arts in Mass Production."

Pump — The Tomkins-Johnson Co., Jackson, Mich. Letter-size leaflet, "The Spiral-Flo Pump."

Pumps—DeLaval Steam Turbine Co., Trenton, N. J. Catalogs: B-6, "DeLaval Propeller Pumps"; L-10, "DeLaval—Imo Oil Pumps."

Rubber—The B. F. Goodrich Rubber Co., Akron, Ohio. Folder entitled "Lubricated with Rubber" describes new line of rubber belting. Catalog Insert No. 2900 on rubber pulley lagging and elevator bucket washers. Catalog Insert No. 9010, "Armorite," a soft elastic rubber used to protect surfaces from abrasion.

Speed Reducers—Foote Bros. Gear & Machine Co., 5301 S. Western Blvd., Chicago, Ill. Catalog No. 301-A, "IXL Hygrade Worm Gear Speed Reducers."

Stainless Steels—Electro Metallurgical Co., 30 E. 42nd St., New York, N. Y. 20-page booklet, "Stainless Steels and Their Uses."

Steel Furniture — Standard Pressed Steel Co., Jenkintown, Pa. Form 454, catalog entitled "Hallowell Stools, Chairs and Tables of Steel."

Stress-Stretch Diagram—The Austin Co., Welding Division, 16112 Euclid Ave., Cleveland, Ohio. "A Stress-Stretch Diagram for Rolled Steel and Cast Iron."

Testing Machines — The Linde Air Products Co., 30 E. 42nd St., New York, N. Y. Two booklets: "Oxweld Portable Tensile Testing Machine" and "Oxweld Extensometer Type TM-3."

Thermal Regulators — Hiergesell Bros., 2522 N. Broad St., Philadelphia, Pa. Bulletin 405, "The 'Red Top' Terminal-Type Thermal Regulator."

Variable Speed Transmission—Reeves Pulley Co., Columbus, Ind. Bulletin T-5645, "Automatic Variable Speed Control."

Vulcanized Fibre — Spaulding Fibre Co., Inc., Tonawanda, N. Y. Two folders, one on fabrication of hard vulcanized fibre; the other on applications of fibre grommets.

Welded Pipe—Republic Steel Corp., Youngstown, Ohio. New Price Card No. 4 on Toncan copper molybdenum iron pipe.

Horsepower Capacities of Spur Gears—I

The following tables give the horsepower rating for a given diametral pitch, number of teeth, and revolutions per minute. These tables are based on the Lewis formula combined with the usual velocity factor given by the Barth equation.

To serve as a guide, the pitch line velocity is also given. Commercial gears are not operated at velocities higher than about 2,400 ft. per min., although higher velocities can satisfactorily be used with hardened and ground gears. For ordinary service the pitch line velocity should not exceed 1,000 ft. per min. when the gears are operating in an oil bath. Excessive oil agitation might cause overheating which can be overcome by resorting to oil pump lubrication.

With grease lubrication the pitch line velocity should be limited to a maximum of about 400 ft. per min. If thick grease is used and the lubrication is intermittent, as when applied by a brush, the carrying capacity of the gears should be reduced to about 65 per cent of that as given in the tables.

The horsepower ratings in the tables are based on cast-iron gears with an allowable static stress of 8,000 lb. per sq.in., this figure assuming an elastic limit of the material of 24,000 lb. per sq.in. For the high quality of the cast irons produced by foundries today this is a safe stress, as proved by the many successful installations. Some engineers prefer to use a static stress of 6,000 lb. per sq.in. for cast iron, particularly for important drives that are in continuous service or when the service conditions are severe or hazardous.

If any stress other than 8,000 lb. per sq.in. is to be used, the horsepower values as given in the tables must be multiplied by the factor obtained by dividing the desired stress by 8,000 lb. per sq.in.

With a stress of 8,000 lb. per sq.in. as a basis, the horsepower rating for any set of gears of any desired combination of materials can readily be obtained by using suitable factors for the different gear materials selected. The various factors for gear materials commonly used are given in the accompanying table. These factors should be multiplied by the tabulated horsepower ratings in order to get the horsepower capacity of the gear made of the given materials.

Material Factors

Gear Material	Elastic Limit of Material	Allowable Static Stress	Multiplying Factor
Phenolic compounds	.....	5,000	0.625
Cast iron	24,000	8,000	1.000
Semi-steel and bronze	36,000	12,000	1.500
Cast steel	45,000	15,000	1.875
Machine steel and forged steel	48,000	16,000	2.000
Casehardened machine steel	.....	32,000	4.000
S.A.E. Heat-Treated Steels			
No. 1030	60,000	20,000	2.500
No. 1045	90,000	30,000	3.750
No. 3230	105,000	35,000	4.375
No. 3245	120,000	40,000	5.000
No. 3215 casehardened	.....	45,000	5.625

The horsepower ratings given in the tables are per inch of face and must be multiplied by the actual net contacting face of the gears in inches to get the total allowable horsepower that can be transmitted. General practice is to limit the face width of the gear to a value of 10 or 12 divided by the diametral pitch. Horsepower ratings of gears having numbers of teeth and running at revolutions per minute not listed in the table can be obtained by interpolation.

The horsepower ratings in the tables are based on the A.G.M.A. standard 14½ deg. pressure angle involute tooth profile, which is in almost universal use at the present time. This tooth form will invarably be furnished by the gear manufacturer unless otherwise specified. When any other tooth form is required, such as the 20 deg. pressure angle full depth or the 20 deg. stub (Fellows) tooth forms, the gear manufacturer must be so informed. Both of the latter tooth forms are much stronger than the 14½ deg. tooth, especially in gears with less than 21 teeth. If either of these tooth forms is used in place of the 14½ deg. involute, a further multiplying factor must be used. These factors are given in the following table:

Multiplying Factors

No. of Teeth	20 deg. Full Depth Tooth	20 deg. Stub Tooth (Fellows)
12	1.139	1.445
13	1.169	1.452
14	1.173	1.440
15	1.180	1.424
16	1.160	1.418
17	1.143	1.398
18	1.139	1.395
19	1.136	1.393
20	1.133	1.389
21	1.131	1.381
23	1.128	1.375
25	1.125	1.373
27	1.121	1.370
30	1.127	1.368
34	1.135	1.366
38	1.152	1.364
43	1.166	1.362
50	1.181	1.366
60	1.186	1.369
75	1.200	1.373
100	1.214	1.376

On the next page is given the tables of horsepower capacity for gears from 1 to 3 diametral pitch. Additional tables will be given next month.

Contributed by C. H. Grill

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REFERENCE BOOK SHEET

Horsepower Capacities of Spur Gears—I

(PER INCH OF FACE WIDTH)

1—Diametral Pitch

R.P.M.		Number of Teeth								
		12	14	16	18	20	25	30	50	100
750	V.	2360								
	H.P.	24.9								
600	V.	1880	2200							
	H.P.	23.7	26.9							
450	V.	1415	1650	1880	2110	2360				
	H.P.	20.6	25.1	28.4	30.6	32.8				
300	V.	945	1100	1260	1415	1570	1965	2360		
	H.P.	19.1	22.2	25.4	27.7	29.8	33.9	36.9		
200	V.	630	735	840	945	1050	1310	1570		
	H.P.	16.0	18.8	21.9	24.1	26.2	30.5	33.4		
150	V.	470	550	630	705	785	980	1180	1965	
	H.P.	13.7	16.4	19.2	21.2	23.3	27.5	30.7	38.5	
100	V.	315	370	420	470	525	655	785	1310	
	H.P.	10.8	13.1	15.5	17.3	19.2	23.1	26.7	34.5	
50	V.	155	185	210	235	260	325	390	655	1310
	H.P.	6.4	8.1	9.7	11.1	12.2	15.6	18.2	26.3	36.7
10	V.	31.5	37.0	42.0	47.0	53	66	79	131	260
	H.P.	1.40	1.79	2.28	2.67	3.10	4.2	5.2	9.0	16.2
1	V.	3.1	3.7	4.2	4.7	5.3	6.6	7.9	13.1	26.2
	H.P.	.140	.179	.228	.267	.310	.42	.52	.95	2.02

2—Diametral Pitch

R.P.M.		Number of Teeth								
		12	14	16	18	20	25	30	50	100
900	V.	1415	1650	1890	2120	2360				
	H.P.	11.0	12.6	14.2	15.3	16.4				
750	V.	1180	1380	1575	1770	1965				
	H.P.	10.3	12.0	13.6	14.7	15.8				
600	V.	945	1100	1260	1415	1575	1965	2360		
	H.P.	9.6	11.1	12.7	13.8	14.9	17.0	18.4		
450	V.	710	825	945	1060	1180	1480	1770		
	H.P.	8.5	9.9	11.5	12.6	13.6	15.8	17.2		
300	V.	470	550	630	705	785	985	1180	1965	
	H.P.	6.9	8.2	9.6	10.6	11.6	13.8	15.3	19.2	
200	V.	315	365	420	470	525	655	785	1310	
	H.P.	5.4	6.5	7.7	8.7	9.6	11.6	13.1	17.2	
150	V.	235	275	315	355	395	490	590	985	1965
	H.P.	4.4	5.4	6.5	7.3	8.1	10.0	11.4	15.6	20.4
100	V.	157	183	210	235	260	330	390	655	1310
	H.P.	3.15	4.0	4.9	5.5	6.2	7.9	9.1	13.1	18.3
50	V.	79	92	105	118	131	164	196	330	655
	H.P.	1.77	2.26	2.80	3.25	3.70	4.8	5.7	8.9	14.0
10	V.	15.7	18.3	21.0	23.6	26.2	33.0	39.0	66	131
	H.P.	.355	.45	.56	.66	.77	1.03	1.29	2.36	4.8
1	V.	1.57	1.83	2.1	2.4	2.6	3.3	3.9	6.6	13.1
	H.P.	.035	.045	.056	.066	.077	.103	.129	.236	.50

1¼—Diametral Pitch

R.P.M.		Number of Teeth								
		12	14	16	18	20	25	30	50	100
750	V.	1885	2200							
	H.P.	18.9	21.6							
600	V.	1510	1760	2010	2260					
	H.P.	17.9	20.5	23.1	24.9					
450	V.	1130	1320	1510	1700	1885	2360			
	H.P.	16.3	18.8	21.5	23.2	24.9	28.3			
300	V.	755	880	1005	1130	1255	1570	1885		
	H.P.	13.9	16.3	18.8	20.5	22.2	25.7	28.1		
200	V.	505	585	670	755	840	1050	1260	2100	
	H.P.	11.4	13.5	15.8	17.5	19.2	22.6	25.0	31.3	
150	V	380	440	505	565	630	785	945	1570	
	H.P.	9.7	11.6	13.7	15.5	16.8	20.1	22.6	29.1	
100	V.	250	295	335	375	420	525	630	1050	2100
	H.P.	7.4	9.0	10.7	12.1	13.5	16.6	18.9	25.6	33.3
50	V.	126	147	168	188	210	260	315	525	1050
	H.P.	4.3	5.4	6.5	7.5	8.5	10.7	12.7	18.8	27.3
10	V.	25.2	29.3	33.5	37.5	42.0	52	63	105	210
	H.P.	.91	1.15	1.43	1.68	1.97	2.64	3.30	6.0	11.1
1	V.	2.5	2.9	3.4	3.8	4.2	5.2	6.3	10.5	21.0
	H.P.	.091	.115	.143	.168	.197	.264	.330	.60	1.28

2½—Diametral Pitch

R.P.M.		Number of Teeth								
		12	14	16	18	20	25	30	50	100
1200	V.	1510	1760	2010	2260					
	H.P.	8.9	10.2	11.5	12.4					
900	V.	1130	1320	1510	1700	1890	2360			
	H.P.	8.2	9.4	10.7	11.6	12.4	14.1			
750	V.	945	1100	1260	1415	1575	1965	2360		
	H.P.	7.6	8.9	10.1	11.0	11.9	13.6	14.7		
600	V.	755	880	1010	1130	1260	1575	1890		
	H.P.	7.0	8.2	9.4	10.2	11.1	12.8	14.0		
450	V.	565	660	755	850	945	1180	1415	2360	
	H.P.	6.1	7.2	8.4	9.2	10.0	11.7	13.0	16.0	
300	V.	380	440	505	565	630	785	945	1570	
	H.P.	4.9	5.8	6.9	7.6	8.4	10.0	11.3	14.5	
200	V.	250	295	335	375	420	525	630	1050	2100
	H.P.	3.70	4.5	5.4	6.0	6.8	8.2	9.5	12.7	16.4
150	V.	189	220	250	285	315	395	470	785	1570
	H.P.	3.00	3.70	4.4	5.0	5.7	7.0	8.1	11.4	15.2
100	V.	126	147	168	188	210	260	315	525	1050
	H.P.	2.16	2.70	3.30	3.75	4.2	5.4	6.4	9.4	13.4
50	V.	63	73	84	94	105	131	157	260	525
	H.P.	1.12	1.43	1.80	2.11	2.46	3.20	3.80	6.1	10.0
10	V.	12.6	14.7	16.8	18.8	21.0	26.2	31.5	53	105
	H.P.	.224	.286	.360	.42	.49	.67	.83	1.52	3.20
1	V.	1.26	1.47	1.68	1.88	2.1	2.6	3.1	5.3	10.5
	H.P.	.022	.029	.036	.042	.049	.067	.083	.152	.320

1½—Diametral Pitch

R.P.M.		Number of Teeth								
		12	14	16	18	20	25	30	50	100
900	V.	1890	2200							
	H.P.	15.8	17.9							
750	V.	1570	1835	2100	2360					
	H.P.	15.1	17.2	19.5	20.9					
600	V.	1260	1470	1680	1890	2100				
	H.P.	14.1	16.2	18.4	19.9	21.3				
450	V.	945	1100	1260	1415	1570	1960	2360		
	H.P.	12.8	14.8	16.9	18.4	19.8	22.6	24.6		
300	V.	630	735	840	945	1050	1310	1570		
	H.P.	10.7	12.6	14.6	16.0	17.4	20.3	22.3		
200	V.	420	490	560	630	700	875	1050	1750	
	H.P.	8.6	10.3	12.1	13.4	14.8	17.5	19.6	25.0	
150	V.	315	365	420	470	525	655	785	1310	
	H.P.	7.2	8.7	10.3	11.5	12.8	15.4	17.5	23.0	
100	V.	210	245	280	315	350	435	525	875	1750
	H.P.	5.4	6.6	8.0	9.0	10.1	12.4	14.4	19.9	26.5
50	V.	105	122	140	157	175	220	260	435	875
	H.P.	3.10	3.85	4.7	5.4	6.2	8.0	9.3	14.1	21.2
10	V.	21.0	24.4	27.9	31.5	35.0	43.5	52	87	175
	H.P.	.63	.80	1.00	1.17	1.37	1.84	2.28	4.2	8.1
1	V.	2.1	2.4	2.8	3.1	3.5	4.4	5.2	8.7	17.5
	H.P.	.063	.080	.100	.117	.137	.184	.228	.42	.89

3—Diametral Pitch

R.P.M.		Number of Teeth								
		12	14	16	18	20	25	30	50	100
1200	V.	1260	1470	1680	1890	2100				
	H.P.	7.0	8.1	9.2	9.9	10.7				
900	V.	945	1100	1260	1415	1570	1965	2360		
	H.P.	6.4	7.4	8.5	9.2	9.9	11.3	12.3		
750	V.	785	920	1050	1180	1310	1640	1965		
	H.P.	5.9	6.9	8.0	8.7	9.4	10.8	11.8		
600	V.	630	735	840	945	1050	1310	1570		
	H.P.	5.3	6.3	7.3	8.1	8.7	10.2	11.1		
450	V.	470	550	630	710	785	985	1180	1965	
	H.P.	4.6	5.5	6.4	7.1	7.7	9.2	10.2	12.9	
300	V.	315	365	420	470	525	655	785	1310	
	H.P.	3.60	4.3	5.2	5.8	6.4	7.7	8.7	11.5	
200	V.	210	245	280	315	350	435	525	875	1750
	H.P.	2.70	3.30	4.0	4.5	5.0	6.2	7.2	9.9	13.3
150	V.	157	183	210	235	260	330	395	655	1310
	H.P.	2.16	2.68	3.20	3.70	4.1	5.2	6.1	8.8	12.2
100	V.	105	122	140	157	175	220	260	435	875
	H.P.	1.56	1.93	2.36	2.72	3.10	3.95	4.7	7.0	10.6
50	V.	52	61	70	79	87	109	131	220	435
	H.P.	.78	1.00	1.25	1.48	1.70	2.28	2.76	4.5	7.5
10	V.	10.5	12.2	14.0	15.7	17.5	21.8	26.2	43.5	87
	H.P.	.156	.200	.250	.296	.340	.46	.58	1.04	2.22
1	V.	1.05	1.22	1.40	1.57	1.75	2.2	2.6	4.4	8.7
	H.P.	.016	.020	.025	.030	.034	.046	.058	.104	.222

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